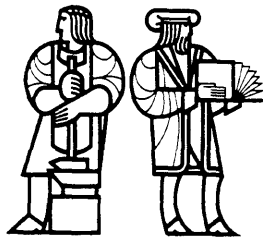

Massachusetts Institute of Technology



Reports to the President

For the Year Ended
June 30, 1991

Massachusetts Institute of Technology



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PRESIDENT

OBSERVATIONS ON THE FIRST YEAR

My first year as president has been marked particularly by the need for MIT to respond to a host of challenging external forces. At a time when I wanted primarily to concentrate on setting a long-range agenda for the future of the Institute and on involving the community in strategic planning, MIT has faced a flood of external actions and issues that have demanded unremitting attention. Some of these issues -- such as the matter of intellectual integrity in the conduct of research -- touch all universities. Other external actions are more narrowly focussed on a few universities -- such as the Justice Department allegations regarding "price-fixing" on financial aid.

Many of these outside forces are troubling, some could be seriously damaging. But while I regret the sheer time and effort that dealing day-to-day with these matters has required, the fact is that they are by no means unrelated to the long-range planning on which we need to concentrate. Indeed, they have served as a lens to bring into focus many of the issues that we must address in defining and shaping our future. They speak to us of a changing nation and world. And many represent an erosion of the partnership between the federal government and our research universities.

CHANGING PUBLIC ATTITUDES

Yet the matter is deeper than the erosion of the sense of partnership between the government and the universities. In our democratic system, the actions of the Congress and the executive branch ultimately reflect the views and will of the people. Thus, we must look more closely at public perceptions and attitudes toward our research universities. MIT historically established the paradigm for these universities and retains its preeminence today; hence these are critical matters for us.

I surmise that the origins of changing public attitudes toward our research universities are twofold:

- First, there is a growing wave of populism and an associated widespread distrust of expertise, excellence, and privilege, whether real or perceived.
- Second, there have been direct assaults, largely on ideological grounds, against our universities. These began in earnest when William Bennett used his pulpit as Secretary of Education to attack American higher education. The flames he ignited were fanned by others, including the picture of the presumed decline of higher education painted by Allan Bloom in *The Closing of the American Mind*, and the intemperate portrait of the American professoriat by Charles Sykes in *Profscam*.

Criticisms of universities have struck a resonance with the public, which had taken account of rapidly rising tuitions and come to believe, almost antithetically, that the quality of teaching and the commitment to undergraduate education, had

degenerated. It is a resonance that we must worry about. It calls for serious self-examination.

CATALYTIC FEDERAL ACTIONS

Against this backdrop this past year came three catalytic federal actions -- the investigations at Stanford of alleged abuses of the system for reimbursement of indirect costs of sponsored research; the further investigation of the matters surrounding fraud charges associated with the *Cell* paper by Weaver, Baltimore, and others; and the continuing investigation by the Justice Department of alleged conspiracy and price-fixing among universities.

While these activities captured the headlines, still other actions were proceeding with less public attention. They included the decline of peer review of academic research and facilities proposals and the corresponding increase in political earmarking; investigations about conflicts of interest on the part of faculty with strong ties to industry; debates about technology transfer from US universities to foreign countries, particularly Japan; criticisms about the numbers of foreign students studying engineering and science in American universities; and a continuing decline in the effective level of federal financial support of students.

DIAGNOSIS AND PROGNOSIS

What does all of this mean? To what extent are these forces aimed at MIT specifically? What is the prognosis? What can we do? There are no definitive answers to these questions, but I would like to share some thoughts about them.

First, what does it mean? It means, basically, that our universities are not immune to the strains present in our society, and that tight budgetary times and shifting, or indeed uncertain, federal priorities are likely to have profound implications for us. It means further that we must strive energetically to understand the forces at work, and their causes, and then develop ways of dealing with them. Thoughtless defensiveness is neither an appropriate nor helpful response. We must listen to and talk with our critics as well as serve as critics. We must correct those areas in need of correction. We must adjust to new realities, recognizing the opportunities and responsibilities as well as the difficulties we face.

When I arrived in Cambridge last fall, MIT had been buffeted by several adverse interactions with various agencies of the federal government in rapid succession. Many believed that there was a strong anti-MIT attitude in the government, but I have not found it so. For over twelve months now, I have made monthly trips to Washington, each with a saturated schedule of visits to senators, representatives, agency heads, and other policy makers. I come away with the impression that MIT is still highly respected and viewed as an important national resource. However, I do not believe that we are viewed as being as far apart from the crowd as we have been in the past. There are also small pockets of resentment of our quality and a belief that, while many other institutions need help, MIT can take care of itself. And there is, most regrettably, a serious lack of recognition of what is required to maintain the wide range of excellence at an institution like MIT and of how very different that is from what is required to build one or two spires of excellence at other kinds of institutions.

What is the prognosis? These are treacherous times. We need to take a leadership role in restoring public confidence in our research universities and in engendering a better understanding of their past contributions and of their importance to a vibrant future. These tasks should follow from our own self-assessment and dedication to leadership in a changing world. Above all, the United States must re-establish a strong and fundamental belief in education and in the importance of scientific and technological research. In his recent book *The Next Century*, David Halberstam speaks of the Japanese educational system. Regardless of one's views of the nature of that system, he states, the Japanese believe that if the young people are educated well, all else can be achieved. It is this attitude -- that the development of our human capital, of people and their ideas, is prerequisite to all else that we want to accomplish -- that we must regain in the United States. If we succeed in doing so, a bright future for the country, and an exciting mission for MIT, will be assured.

CHANGING FEDERAL RELATIONS

Let me now turn to some of the specific elements in the nature of MIT's relationship to the federal government that require careful analysis and action. We begin that task from a history and background of strength. Previous MIT administrations have been very well represented in the highest councils of the executive branch. Moreover, MIT faculty remain very well connected to the agencies of the federal government. They are sought out for service on key planning panels and understand the missions of the agencies very well. Nonetheless, I believe that the Institute today needs new responses to the apparent growing shift of responsibility for science and education policy into the more chaotic domain of the Congress. In addition to devoting a major portion of my own time to federal issues, I concluded early on that it would be wise to have a continuous presence in Washington. Accordingly, we have opened an MIT Washington Office, directed by Dr. John C. Crowley, former vice president of the American Association of Universities. This office will enable us to observe and interact more continuously with federal policy initiatives, and the related authorization and appropriations processes that affect us and our colleagues. We intend to work largely through coalition building and close collaboration with our sister institutions. The Washington Office will also serve as a gateway to MIT, assisting in bringing MIT faculty expertise to both principals and staff members in the Congress and in the executive branch. Good scientific and technological advice is needed as never before in the government, and our faculty can contribute much.

Indirect Costs of University Research

The subject of indirect costs of university research, long considered something of an arcane topic, became headline news in 1991 as a result of allegations of erroneous and inappropriate charges to the federal government by Stanford University. The subsequent government investigations riveted both Congressional and public attention on indirect costs of research, and on the accounting/auditing procedures used to reimburse universities for those costs. These investigations, and the manner in which they were conducted and reported by the press, have tended to erode public confidence in our universities and have unleashed forces in Congress and elsewhere that have the potential to do great damage to the nation's system of higher education and research.

These investigations have also raised authentic issues, however, and the response of the university community must be to correct any legitimate problems. In particular, further tightening, clarification, and greater standardization of accounting

procedures are needed to prevent erroneous charges to indirect cost pools. What is not needed is a rush to judgment that will produce an ill-considered quick fix that will harm the long-term health of our universities and our national system of research. I am particularly concerned that the responsibility for indirect cost matters should remain centered in the executive Office of Management and Budget (OMB). The specter of the details of indirect cost accounting becoming part of the annual appropriations process in the Congress is daunting.

A particularly troubling aspect of the present indirect cost debate is the lack of recognition of, or commitment to, the concept that federal research support to universities serves the dual purpose of accomplishing research and educating graduate students, who comprise the next generations of researchers. In some of the debate, funding of university research has been viewed as a simple government procurement -- an approach that draws no distinction between supporting university research, with its intimate involvement of graduate students, and purchasing goods and services from an ordinary supplier. This approach also appears to be promoted by some funding agencies which support policies that effectively encourage the employment of postdoctoral researchers rather than graduate students. In an era when projections show looming shortfalls in the numbers of Ph.D. scientists and engineers in the US, such an approach is unwise, and we have worked hard to counter it wherever we have found it.

Relatedly, we are concerned about recommendations by some to disallow the payment of graduate research assistants' tuitions as employee benefits. The disallowance of this practice would drive an immediate two-thirds increase at MIT in the annual cost of supporting a graduate student research assistant on an individual faculty grant or research contract. A lack of supportiveness of the graduate student component of research is also displayed in various proposals for handling the partial support of library costs and the recommendation by some in Congress that the student services component of indirect costs be eliminated.

Fundamental to the process of restoring confidence in this system of cost accounting is the tenet that policies and practices should be based on principles. Therefore, I believe it is particularly important now, while we are reviewing these accounting guidelines, that we not lose sight of the fundamental principles of OMB Circular A-21, which has governed for many years the financial relationships between government and universities receiving federal funds in research. In brief, these principles are that university faculty, graduate students and staff will perform research at low cost, and that simultaneously they will maintain and advance the scientific, technological and intellectual infrastructure of America by educating the next generation of researchers. In return, the US government will recognize the diversity among American universities and the dual role of graduate students in research and education, and will bear its full and fair share of costs. These philosophical and economic principles have proved extraordinarily sound and have helped make this country's university research system the world leader. Any restructuring of Circular A-21 must be solidly based on considered analysis, careful redefinition, and the preservation of the principles that have served so well.

Academic Integrity

Universities exist to pass on knowledge to succeeding generations and to generate new knowledge, analyses, and insights. We, in addition, have an overarching responsibility -- to imbue in our students and ourselves a dedication to intellectual honesty as well as an understanding of the methodologies of objective analysis and the respect for reasoned discourse that lead to the establishment of scientific and scholarly truth.

Recently, a few highly publicized cases of alleged scientific misconduct have captured the public's attention. While the press and others seek to sensationalize these events, we must do more than attempt to persuade the public that if such misconduct has occurred it is a rare event -- as in fact it is. In every case of alleged misconduct, we must look to the substance behind allegations, and we must continually review and refresh our commitment to basic academic values.

What are these values? What is the foundation of scientific and scholarly research that we hold fundamental? The foundation is truth, and certain intimately related concomitant values, which Jacob Bronowski identified so well in his book of essays, *A Sense of the Future*. As discussed by Bronowski, these include, importantly, independence and originality; a belief in the value of dissent; and an adherence to freedom of thought and speech. Central to these values is the importance of respecting another's point of view. Points of view and hypotheses are there to be debated, tested, proved, disproved, revised, built upon, or rejected. This is what makes science -- indeed most scholarship -- both an individual and a highly communal activity. And it is why we say science is a self-correcting enterprise that strongly counters any forces that might tempt one to cut corners or act with less than full honesty.

Nonetheless, there are forces that push the modern university researcher in other directions. Among them are the following:

- First, the *rapid expansion and communication of knowledge*. Nearly instantaneous promulgation of research results by various modern means contributes to a sometimes frenetic pace that can run counter to the careful review and reworking of research that might reduce ultimate error.
- Second, the *nature of incremental advances in some fields*. In some fields undergoing rapid development, it is often the case that relatively modest advances may have great, albeit fleeting, significance. This, too, can produce a rush to disperse results that can reduce care, review, and reflection, thereby increasing the probability of error.
- Third, *the culture of instantaneous news and fame*. Scientists and scholars do have egos. They are often highly competitive, a characteristic that generally works to the advantage of science. However, when this trait is combined with the American public's unquenchable thirst for sensation and for daily dosages of revolutionary advances, extraneous temptations and inappropriate forces are created.

- Finally, the opportunity for *monetary gain*. Universities have become great engines of the modern economy, and we have increasingly worked together with profit-based industries in arrangements which have contributed significantly to the common good. Yet some of these ties between university scientists and the corporate world, with their enhanced opportunities for personal financial gain, may not always be free from the possibility of troubling conflict of interest.

The basic challenge before us is to do a better job of passing on and strengthening our system of values. How can this be accomplished? The easy suggestion is to establish formal courses and perhaps require them of all students. But this is not necessarily practical or effective. We can, also, as I have asked MIT to do, establish broader mentoring of new colleagues -- faculty and students -- and create occasional forums designed to help develop an environment in which the importance of intellectual integrity and scholarly values are widely understood and prized. Ultimately, however, it is in our individual and institutional actions that our values are manifested. Whatever we say, we teach by example. And the lesson will be conveyed best, therefore, by the ways in which we undertake our own scholarly activities and by the ways in which we deal with problems if they do arise.

We have heard great outcries, for and against, the policing of science. Our response, as an academic community, must not be one of knee-jerk defensiveness, but rather one of developing an effective method of self-governance regarding integrity in research. If we are not able to do so, we can be sure that others will be only too glad to do it for us. And what we don't need is more bureaucracy and increased overhead expenses for programs to enforce scientific integrity. To strengthen our self-governance at MIT, the Provost and I asked a group of distinguished faculty, chaired by Professor Sheila E. Widnall, to review our responsibilities and articulate our values in the conduct of academic research; to look at our own policies and procedures in light of those values; to compare these policies and procedures with federal and professional standards and guidelines governing research, and to suggest revisions where appropriate; and, finally, to propose creative ways of introducing mentoring and educational programs regarding both the conduct of research and the provision of broad career guidance throughout the entire academic community. This committee has produced an interim report which will provide the framework for Institute-wide discussion during the fall and lead to a set of specific recommendations thereafter.

Student Financial Aid and the Justice Department

A rather strange episode in our relations with the federal government continues to play itself out in a suit against MIT by the Department of Justice. Since 1989, a number of universities and colleges have been the subjects of an investigation by the Department of Justice seeking evidence that they have conspired and violated the Sherman Antitrust Act. Hoards of government attorneys have, at great expense to the American taxpayer and to those who pay tuition and make charitable donations to these schools, combed through the records of this "industry" to spot evidence of "collusion" in restraint of trade that would suppress free market forces acting upon faculty salaries, tuition charges or financial aid to students. In May, the US Attorney General brought a formal complaint against the eight Ivy League universities and MIT for colluding in the Overlap Group -- meetings held by those institutions to assure that their student financial aid to applicants in common be awarded only on the basis of financial need.

The eight Ivy League universities settled the complaint out of court by agreeing not to engage in this practice for the next ten years. MIT, after careful deliberation, decided not to sign this consent decree and therefore is being sued by the Department of Justice. We took this position for three reasons. We do not believe that we have violated the Sherman Act; we believe that there are distinguishing differences between us and the other eight universities in this matter; and we believe that our approach to need-based financial aid, and the manner in which its implementation was assisted by the Overlap Group, serves an important social function and is the best use of the limited financial aid funds available to us. We do not believe it is in the nation's interest for universities to compete financially for students.

The Department of Justice, apparently believes that financial aid would be better based on merit. They conclude that if the highly competitive schools named in their action had not jointly agreed to provide aid based on need, that some students would have received greater financial assistance, and therefore a lower effective price for their educations, and that this would be appropriate. MIT, on the other hand, has long believed that, while students should be admitted to the Institute on the basis of intellectual merit, they should be awarded financial aid based solely on their, and their families, ability to pay. Ironically, and remarkably, this long-standing MIT student aid policy is exactly the approach that was later mandated by the Congress for the use of federal financial aid funds to undergraduates.

MIT has and will defend its beliefs in this suit in a considered manner, seeking thoughtful and expert advice, and remaining cognizant of all the costs and ramifications of its actions.

THE CHANGING FACE OF AMERICA: IMPLICATIONS FOR MIT

Besides these federal actions, there are a number of other external issues that impinge strongly upon us. Foremost among them, and one of deep concern is the issue of race in America. Universities are both susceptible to aspects of this issue and, in my view, responsible for working vigorously toward the solution of certain components of it. Moreover, regardless of differing views regarding the social responsibilities of higher education, the fact remains that the racial and ethnic structure of the American populace and workforce is changing rapidly in well known and absolutely predictable ways. Students who are to be optimally educated for the world they will enter must learn from the experience of living and learning with, and from, students and faculty representing the diversity of people who now comprise the country. Furthermore, as we look at the various projected shortfalls of engineers, scientists and Ph.D. level scholars in numerous fields, it becomes apparent that attracting and educating people from segments of our population who have traditionally not been well represented in academe is in the national interest.

MIT has played a leadership role by significantly increasing the numbers of underrepresented minority students in our undergraduate programs. Underrepresented minority students make up 16 percent of the class of 1995. Enrollments in our graduate programs, and representation on our faculty, of underrepresented minority scholars, however, have not kept pace. It is imperative that we improve this situation appreciably. At the faculty level, the Provost has recently announced a reinvigorated, funded program designed to assist departments

financially in increasing the number of underrepresented minorities on the MIT faculty. We also are accelerating the conduct of programs aimed at making the opportunities for graduate study at MIT clearly known to underrepresented minority undergraduate students around the country.

MIT has also played a leadership role in the education of women in engineering and the sciences. Women comprise 35 percent of the new entering class. Substantial progress has been made during the last two decades also in attracting women to our graduate programs and to our faculty, but more remains to be done. Here, too, the Provost will provide certain assistance for hiring women, especially at tenured levels in departments where they constitute less than a quarter of the faculty.

But attracting a more diverse faculty and student body to MIT is only part of the challenge before us. The entire environment for living and working in our universities needs concerted attention as the society of which we are a part changes. Single parents, dual-career couples, and an aging population have become the norm. Although the university cannot be expected to solve all of the problems that accrue from these changes, they require that we give proper attention to the development of a campus that is open, rewarding, and satisfying. Accordingly, following the recommendation of a recent faculty and staff committee, a Council on Family and Work will be appointed to advise and assist the administration in establishing at MIT the most satisfying environment possible.

MIT: A NATIONAL AND AN INTERNATIONAL UNIVERSITY

Yet another set of challenges has to do with the increasing interdependence of peoples and enterprises throughout the world. Our world is interconnected as never before -- through our physical environment, through communications networks, through our production and economic systems, through politics and through expanding common knowledge bases. Similarly, our research universities have become increasingly international, an inevitable change that has led some legislators and others to question the nature of the international connections of research universities in general, and of MIT in particular.

The basic questions are obvious. Is it appropriate that so many international students are studying science, engineering and business in American universities? Nationally, for example, approximately 50 percent of the graduate students in engineering and physical science are foreign citizens, while at MIT one-third of our graduate students come from other countries. Is it appropriate for universities to receive support in the form of donations, or research funding, from foreign countries and companies? And the most difficult, and emotionally charged, question -- given that our universities receive so much federal research support -- do foreign companies "skim the cream" by carrying off critical technological knowledge, commercializing it, and then outcompeting US firms?

During much of this past year an Institute-wide committee chaired by Professor Eugene B. Skolnikoff considered these and other issues involving our international connections, and proposed a number of policies for MIT. We have disseminated this report widely around to colleagues in government and industry, and it has received, generally, very favorable comment.

The basic principle set forth in the report is that MIT is first and foremost an American institution. We have, and will, serve the United States well. We best serve our nation, however, by being a preeminent institution of higher education and research emphasizing science and engineering. We can maintain this preeminence only if we maintain strong intellectual, professional, and personal ties throughout the world.

Science has always prided itself in its internationalism -- judging people and ideas on their merit alone. This principle served us well earlier in this century when large numbers of American scholars studied in Europe, bringing back leading-edge knowledge and establishing fine academic departments and laboratories here. American universities also value greatly the numerous faculty who have emigrated to this country and have become great academic and scientific leaders. I believe that we are now entering an era when the flow of scholars and knowledge across many national boundaries will be the prerequisite for first-rate science and technology, and for first-rate universities. We must act accordingly.

The issue is admittedly complicated to an extent because of the diminished distinctions between basic and applied research in many fields, the shortened times from laboratory to commercialization, and the more intimate relationship between universities and industry. However, I believe that it would be a serious strategic error for the country to attempt to establish impermeable boundaries around our universities. Rather, we must work to gain more assurance that communications with visitors to our laboratories are two-way, that knowledge and expertise flow in as well as out.

Having said this, I believe that the fraction of international students in US graduate science and engineering programs is too high. It should be a goal of our secondary and undergraduate schools to educate and inspire US students to move into such demanding and important programs of study rather than standing aside while more intellectually energetic and disciplined students from other nations take up the challenges. Furthermore, we must educate our US citizen students appropriately and encourage them to gain experience overseas, that is, we must prepare them for leadership in the kind of world in which they will live and work. MIT's Japan Program, to cite an instance, is an outstanding example of leadership in this area.

EDUCATION AT MIT

All aspects of undergraduate education continue to be very actively discussed at the Institute, as they are in public forums, where university faculty are frequently criticized for allegedly caring more about graduate education and research than undergraduate teaching.

While American students themselves appear to be satisfied in many dimensions, they seem also to have the sense that somehow things should be better still. Undergraduates often believe that they have too many teaching assistants as instructors, not enough direct faculty contact, and insufficient academic and career counselling. And such criticism is aimed most often at research universities, the

thesis being that undergraduate teaching is not valued there and that faculty often neglect their teaching responsibilities because of the emphasis on research.

With this criticism in mind, I recently asked one of our graduating seniors how he had found the quality of teaching at MIT. He answered that it was excellent in the lower level subjects, but spread over a wide range in the more advanced subjects. Expanding on this, he explained that the faculty expended enormous effort and creativity in doing a truly first-rate job in the large freshman and sophomore introductory classes, but that a student was expected to learn more independently -- more like a junior colleague, if you will -- in many of the more advanced subjects. This senior's response demonstrates yet another aspect of MIT's uniqueness. At most research universities the usual complaint is that the faculty seem uninterested in the large introductory courses, and only as one progresses into the advanced classes does their interest become more deeply engaged.

What then is the situation regarding undergraduate teaching at our research universities, and at MIT in particular? In contrast to what some educators are arguing today, I believe that the American research university has created a matrix within which the best possible education for the twenty-first century can take place. Its novel blending of undergraduate education, graduate education and research is what truly makes these universities the best in the world. At MIT, moreover, there is a permeating belief that our undergraduate curriculum and education constitute our institutional core and are the key to our national and world leadership. Still, vigilance is required to maintain teaching excellence and to renew and revitalize the curriculum. I believe that our record in this respect is exemplary.

In a major curriculum development this past year, the faculty voted to establish a subject in modern biology as a new General Institute Requirement for undergraduates, effective with the class entering in 1993. We believe that we are the first university to recognize, by requiring it of all students, the growing general importance of modern biology and the uniqueness of its methodologies. This will enhance still further the quality and relevance of an MIT education.

I am pleased to report also something of a quiet revolution in student counseling and personal contact between students and faculty. As we enter 1991-92, so many faculty have decided to offer freshman advisor seminars that over two-thirds of our new students are having the experience, at the very beginning of their MIT education, of meeting weekly in small groups with Institute faculty for study, discourse, and counselling.

To encourage further attention to teaching, we have just established a program of Faculty Fellows. These endowed awards will recognize faculty for outstanding contributions to our undergraduate educational programs. They are intended to have associated with them a level of prestige equivalent to endowed professorships, and will provide a discretionary scholar's allowance for a period of ten years. The Provost will solicit nominations from the community and will appoint approximately six Fellows per year. Thus, over a decade, on the order of sixty outstanding teachers will be acknowledged in this manner.

A PERSONAL NOTE

In my first presidential report I have concentrated on a few trends and problem areas that are of particular significance nationally and at MIT in 1991. There is so much more that could have usefully and pleasurably been addressed. Since accepting the privilege of serving this great institution, I have found MIT to be intellectually vibrant, replete with creativity and entrepreneurship, well managed, and a great asset to this nation and world.

On a personal note, Becky and I wish to express our deep appreciation for the manner in which we have been accepted and welcomed by the MIT community. To have that friendship, warmth and collegiality coexist so wonderfully with the excellence and professionalism of our faculty, staff and students has made our transition to our new home and institution fully as much a pleasure as it has been an honor.

MIT's commitment to education, its uniqueness in mission and education, and its effective service beyond the confines of its campus have served the nation and world well for many decades. Our central challenge is clear: to continue and enhance MIT's excellence through these uncertain and changing times and into the next century. For my own part, I accept that challenge fully and enthusiastically.

CHARLES M. VEST
October, 1991

In Special Recognition

This was a year of important changes in the administration of MIT, several of them attendant upon the arrival of a new president.

The first to be mentioned, of course, is the election of Paul E. Gray to Chairman of the Corporation after ten extraordinarily distinguished years as MIT president. It is a great comfort to have Dr. Gray continuing his unbroken years of service to MIT, now as the leader of the Institute's board of trustees. His remarkable background as student, alumnus, professor, dean, chancellor and president give him unique perspectives and insights for his new role at the helm of MIT's governing body. On a personal level, I am buoyed by his invaluable advice and support and look forward to a continuation of a close and productive relationship for many years to come.

It was a special pleasure, as one of my first official acts, to appoint Mark S. Wrighton, CIBA-GEIGY Professor of Chemistry as Provost of the university. Professor Wrighton is a faculty member whose intellect, devotion to teaching, willingness to serve others, knowledge of the Institute and dedication to MIT are widely recognized among his colleagues and we are fortunate to have him accept this appointment as MIT's chief academic officer. As head of the Chemistry Department since 1987 and a scientist of world renown, Dr. Wrighton also enjoys the respect of the larger academic community beyond MIT. I am delighted to have him by my side as my principal deputy.

In this eventful year, three new school deans have been appointed by the Provost:

In January, Professor Joel Moses, Dugald C. Jackson Professor of Computer Science and Engineering and head of the Department of Electrical Engineering and Computer Science from 1981 to 1989, was named Dean of the School of Engineering. Dean Moses, renowned for the development of MACSYMA, the largest computer system for symbolic algebraic manipulation, has been a member of the faculty since 1967 and is recognized for making significant contributions to both computer science and computer engineering. He succeeded Professor Gerald L. Wilson, who, as noted in last year's report, is on leave from MIT after nearly 10 years of outstanding leadership as Dean.

In May, Professor Robert J. Birgeneau, internationally respected as a leader in condensed matter physics and head of the Department of Physics since 1988, was named to succeed Professor Gene M. Brown as Dean of the School of Science. Dean Birgeneau, who came to MIT as Professor of Physics from the Bell Laboratories in 1975, has a well-established track record of enhancing the participation of women and minorities in science and is dedicated to excellence in education and research. His own research has focused on a series of experiments carried out with colleagues in his department and in the Center for Materials Science and Engineering aimed at explaining high-temperature superconductivity.

Professor Brown concluded his term as Dean of Science after six years in that role. Dr. Brown, Professor of Biochemistry, has resumed his faculty responsibilities in the Department of Biology, which he headed from 1977 until his appointment as dean. He has served MIT well, both in the faculty and in the administration. While head of biology, he contributed significantly to its development as a world-class department; as dean, he provided School-wide leadership, maintaining and continuing his commitment to excellence in education.

In June, Professor Philip S. Khoury, was named Dean of the School of Humanities and Social Science after serving as acting dean for a year. Before becoming acting dean, Dr. Khoury, Professor of History in the History Faculty, had been associate dean since 1987. In these posts, he has been deeply involved in the School's ongoing reassessment of the undergraduate curriculum. Dean Khoury, who joined the MIT faculty in 1981, is widely regarded as a leading historian of the modern Middle East. His scholarly work includes a strong background in comparative urban history and politics and in comparative nationalist movements.

Professor Arthur C. Smith was appointed to a two-year term as Dean for Student Affairs after serving as acting dean since July 1990. Dr. Smith, Professor of Electrical Engineering, former graduate officer in the Department of Electrical Engineering and Computer Science, and former chairman of the faculty, has long been an effective advocate for the Institute's students.

Dean John de Monchaux of the School of Architecture and Planning announced in May that he will conclude his term as dean on January 15, 1992. After a period of leave, he intends to return to MIT as a professor in the Departments of Architecture and Urban Studies and Planning. In his ten years as dean, Professor de Monchaux has contributed to the leadership of the Institute in a wide range of matters, with a particular interest in the physical appearance of the campus and the function of the plant. In his School, he has effectively addressed the urgent problems of financial aid, academic computing, affirmative action, and space.

Kenneth A. Smith, Associate Provost since 1980 and and Vice President for Research since 1981, resigned those positions and his role as Director of MIT's Whitaker College of Health Sciences and Technology to return to the Department of Chemical Engineering, where he is the Edwin R. Gilliland Professor. Professor J. David Litster, Director of the Francis Bitter National Magnet Laboratory since 1988 and a member of the Physics Department, was named to the vacated posts on an interim basis. Dr. Litster, who joined the MIT faculty in 1966, was Director of the Center of Materials Science and Engineering for five years before becoming Director of the Magnet Laboratory.

Two special appointments were made this year:

Carl M. Mueller, Class of 1941, who for more than two decades served MIT as a member of the Corporation and as chairman of three presidential search committees,

of which he chaired two, was named an honorary lecturer by the Corporation -- a rare action -- in recognition of "his trustee leadership and unparalleled contributions."

Dr. David S. Saxon, who served as Corporation Chairman from 1983 to 1990, was named Honorary Chairman, succeeding Howard W. Johnson, who resigned to permit Dr. Saxon's election to the position.

New department or academic program heads announced during the past year were:

Elizabeth Drake and William A. Peters, Associate Directors, Energy Laboratory; Thomas W. Eager, Director, Materials Processing Center; Stephen C. Graves and Robert B. McKersie, Deputy Deans, Sloan School of Management; Richard O. Hynes, Director, Center for Cancer Research; John G. Kassakian, Director, Laboratory for Electromagnetic and Electronic Systems; Alan P. Lightman, Head of the Writing Program; Borivoje B. Mikic, Associate Head, Department of Mechanical Engineering; Ernest J. Moniz, Head, Department of Physics; Robert J. Silbey, Head, Department of Chemistry; Phillip A. Sharp, Head, Department of Biology; Nam P. Suh, Head, Department of Mechanical Engineering; David N. Wormley, Associate Dean, School of Engineering.

Among key changes in the administration during the past year were the promotion of David S. Ferriero as Associate Director for Public Services, MIT Libraries, and the appointment of Gregory A. Jackson as Director, Educational Studies and Special Projects in the Office of the Dean for Undergraduate Education.

* * *

The honors and achievements of MIT faculty and staff have been many this year. In this part of the report I mention only some of the individual efforts and awards which have given such distinction to the Institute.

Professors Jerome I. Friedman and Henry W. Kendall of the Department of Physics and the Laboratory for Nuclear Science shared the 1990 Nobel Prize for Physics with Professor Richard E. Taylor of the Stanford Linear Accelerator Center for research done at the Center from 1967 through 1973. Their seminal investigation provided the first experimental evidence for subnuclear particles called quarks, the most fundamental constituents yet known of heavy particles such as protons and neutrons. Their award, with that of an alumnus, Elias J. Corey Jr. (MIT S.B. 1948, Ph.D. 1951), who won the 1990 Nobel Prize in chemistry, brought to 24 the number of faculty members, staff and alumni who have won Nobel Prizes since 1956.

Edward N. Lorenz, Professor of Meteorology, Emeritus, and Senior Lecturer in the Department of Earth, Atmospheric and Planetary Sciences, won the 1991 Kyoto Prize for basic sciences in the field of earth and planetary sciences. Renowned for his work in the dynamics of atmospheric circulations, Professor Lorenz was the first to

recognize what is now called chaotic behavior in the mathematical modeling of weather systems. The annual Kyoto Prizes, which have been likened to the Nobel Prizes in prestige and monetary value, are given by the Inamori Foundation of Japan. Professor Lorenz is the fourth MIT faculty member to become a Kyoto Laureate.

Mildred S. Dresselhaus, Institute Professor and Professor of Electrical Engineering and Physics, was awarded the National Medal of Science "for her research in the electronic properties of metals and semimetals and for her work in developing wider opportunities for women in science and engineering." She became the sixteenth member of the faculty to receive the medal, established by Congress to recognize achievements in physical, biological, mathematical, behavioral, social or engineering sciences.

Four faculty members were elected to the National Academy of Engineering: Robert A. Brown, Arthur Dehon Little Professor of Chemical Engineering and head of the department; Thomas L. Magnanti, George Eastman Professor of Management in the Sloan School; Frank A. McClintock, Professor of Mechanical Engineering, Emeritus; and Earll M. Murman, Professor of Aeronautics and Astronautics and head of the department.

Two faculty members were elected to the National Academy of Sciences: Professor H. Robert Horvitz of the Department of Biology, and Professor Patrick A. Lee, William and Emma Rogers Professor of Physics.

Phillip A. Sharp, John D. MacArthur Professor of Biology and head of the department, was elected to the Institute of Medicine.

Fourteen faculty were elected as new Fellows of the American Academy of Arts and Sciences: Amar G. Bose, Professor of Electrical Engineering; Jill Conway, Visiting Professor of the History of Women; John W. Dower, Henry R. Luce Professor in International Cooperation and Global Stability in the History faculty; Ann M. Graybiel, Professor of Neuroanatomy; Jerry A. Hausman, Professor of Economics; Paul L. Joskow, Mitsui Professor of Economics; Patrick A. Lee, William and Emma Rogers Professor of Physics; Leonard S. Lerman, Senior Lecturer in Biology; George Lusztig, Professor of Mathematics; Uttam Lal RajBhandary, Professor of Biochemistry; Robert J. Silbey, Class of 1942 Professor of Chemistry; Merritt Roe Smith, Metcalfe Professor of Engineering and the Liberal Arts; Daniel W. Stroock, Professor of Mathematics; JoAnne Stubbe, Professor of Chemistry; and Charles M. Vest, President and Professor of Mechanical Engineering.

Robley D. Evans, Professor of Physics, Emeritus, and one of the founders of the field of nuclear medicine, was one of two recipients of the 1990 Enrico Fermi Award, the US Department of Energy's highest scientific honor. Dr. Evans was cited for "occupying a special place in the history of radiation physics and biology and the development of our understanding of radiation effects." He was the fourth person from MIT to receive the award.

Bernard F. Burke, William A.M. Burden Professor of Astrophysics, was appointed a member of the National Science Board, the governing body of the National Science Foundation.

Seymour A. Papert, Professor of Education and Media Technology, LEGO Professor of Learning Research and Director of the Epistemology and Learning Group at the Media Laboratory, was selected as the 1991 winner of the Louis Robinson Award given by EDUCOM, a Washington-based nonprofit consortium of colleges, universities and other institutions to promote the effective use of computers and communications technology in higher education. Professor Papert, inventor of the computer language LOGO, was cited for "his innovative contributions to the fields of artificial intelligence and educational computing."

Professor Robert W. Balluffi, Professor of Physical Metallurgy, received the 1990 Von Hippel Award from the Materials Research Society. The society's highest honor recognizes scientists who have had a major impact on materials research. The citation noted that his "research on grain boundaries in metals, ceramics and semiconductors has shed light on a wide range of fundamental scientific and technological problems."

Eugene E. Covert, Professor of Aeronautics and Astronautics, was awarded the von Karman Medal by NATO's Advisory Group for Aerospace Research and Development (AGARD). The award stated that Professor Covert "greatly stimulated international cooperation and exchange of technical-scientific information with substantial benefit for the Alliance."

William F. Schreiber, Professor of Electrical Engineering, Emeritus, received the David Sarnoff Gold Medal Award from the Society of Motion Picture and Television Engineers. The award recognizes outstanding contributions in the development of new techniques and equipment that have contributed to the improvement of the engineering phases of television. From 1983 to 1989, Professor Schreiber was director of advanced television research at MIT.

Robert G. Gallager, Fujitsu Professor of Electrical Engineering and Co-Director of the Laboratory for Information and Decision Systems, won the Institute of Electrical and Electronics Engineer's (IEEE) highest award, the IEEE Medal of Honor for his contributions to "communications coding techniques which have wide-ranging applications in facsimile transmission, electronic bulletin boards, compact disc players, cellular radio, data storage and space exploration."

Theodore A. Postol, Professor of Science, Technology, and National Security Policy, was given the American Physical Society's Leo Szilard Award "for his incisive technical analysis of national security issues that has been vital for informing the public policy debate."

Within the Institute, two faculty members -- John M. Deutch, Professor of Chemistry and former Provost, and Jerome I. Friedman, Professor of Physics -- were named Institute Professors. This title is an honor bestowed by the faculty on a colleague for leadership and extraordinary accomplishments in the scholarly, educational, and general intellectual life of MIT and the wider academic community. There are generally no more than 12 active Institute Professors on the faculty.

Noam A. Chomsky, Institute Professor and Professor of Linguistics, whose theories on the nature of language have revolutionized linguistic science, was selected as the 1991-92 recipient of the James R. Killian Jr. Faculty Achievement Award, which recognizes extraordinary professional accomplishments and service to MIT. The selection committee's citation credited Dr. Chomsky as "the recognized leader in the scientific study of language" whose scholarly work has "transformed linguistics from a huge but ineffective accumulation of imperfectly understood facts into a coherent empirical and theoretical science."

Mehran Kardar, Class of 1948 Associate Professor of Physics, was named the 1991 recipient of the Harold E. Edgerton Faculty Achievement Award, given annually to a junior faculty member in recognition of exceptional teaching, research, and scholarship. The selection committee said Professor Kardar's "extraordinary talents and commitment in physics research are matched by his talents and commitment as a teacher, by his good citizenship within the Institute community, and by his general friendliness, selfless helpfulness and dignified modesty."

The Institute was saddened this year by the deaths of several longtime friends and colleagues.

Walter Carlisle (Carl) Barber, Professor of Physics, Emeritus, died on November 11 at the age of 71. Before coming to MIT, Professor Barber was director of the High Energy Physics Laboratory at Stanford University where he built the first medical linear accelerator for the treatment of cancer. In 1968 he became a member of the MIT physics faculty and did research on the linear electron accelerator at the MIT-Bates Laboratory.

Alan H. Barrett, Professor of Physics, Emeritus, died on July 3 at the age of 64. Dr. Barrett was widely recognized for his scientific contributions to the field of radio astronomy and to the radiometric study of the interstellar medium. He also applied the methods of radio astronomy to the study of the earth's atmosphere and to noninvasive measurements of the human body. Dr. Barrett joined the faculty of MIT in 1961 and, in October 1963, he and his associates at MIT were the first to detect and measure the presence of hydroxyl, or OH radicals, in interstellar space. He also codesigned microwave detection equipment carried into space on the Mariner I and II vehicles.

Edward L. Bowles, an electrical engineer who was a pioneer in communications engineering at MIT in the 1920s and 1930s, died September 5 at the age of 92. Professor Bowles was a member of what was then called the Department of Electrical Engineering from 1925 to 1952 and then of the Sloan School of Management until 1963. In World War II, he organized a defense against the rocket "buzz bombs" Germany had begun using against England. The system succeeded in destroying more than 90 percent of the bombs in the air.

Edward Pennell Brooks, the founding dean of the Sloan School of Management from 1951 to 1959, died on February 22 at the age of 95. Dean Brooks received a Bachelor of Science degree in business and engineering administration from MIT in 1917. He served in both world wars, was a consultant to the federal government, and organized and chaired numerous international committees. Professor Brooks was chosen by the late MIT President James R. Killian, Jr. to head a new school of management at the Institute, which later became the Sloan School of Management. He was a member of the MIT Corporation from 1941 to 1946. Mr. Brooks retired in 1960 as dean emeritus and professor emeritus.

John F. Elliott, Professor of Metallurgy, died on April 15 at the age of 70. Professor Elliot took his doctorate degree from the Department of Metallurgy at MIT in 1949 and joined the faculty in 1955. For more than four decades, his name was associated with outstanding leadership in chemical-process metallurgy and in the specific field of steelmaking. Since 1978, Professor Elliott had been director of the Mining and Mineral Resources Research Institute created by the US Bureau of Mines at MIT.

Frederick Gardiner Fassett, Jr., first dean of residence at MIT, died on January 7 at the age of 89. Dean Fassett joined the Humanities faculty in 1930 and later became editor of *Technology Review* and director of the Summer Session and of the Technology Press (now the MIT Press). He was appointed associate dean of students in 1950.

Kenneth J. Germeshausen, widely-known scientist and inventor, co-founder of EG&G, Inc., and Life Member Emeritus of the MIT Corporation, died September 9, 1990 at the age of 83. Mr. Germeshausen, who received the S.B. degree in electrical engineering in 1931, was one of MIT's most distinguished and dedicated alumni. Through the generosity of the EG&G founding partners -- the others were MIT graduates Harold E. Edgerton and Herbert E. Grier -- and their company, the EG&G Education Center was created. Mr. Germeshausen and his wife, Polly, also endowed the Germeshausen Professorship to further MIT's interest in combining humanitarian advances with technological progress.

David H. Frisch, Professor of Physics, Emeritus, died on May 23 at the age of 73. Professor Frisch earned his Ph.D. at MIT in 1947 and joined the faculty in 1948. He helped develop the atom bomb in World War II and later became active in the disarmament movement. A specialist in the field of nuclear and elementary particle physics, his research interests were wide-ranging. Professor Frisch served on the Physics Advisory Committee of the National Science Foundation, on the Brookhaven High Energy Advisory Committee and, as chairman, on the Long-Range Planning Committee of the Fermi National Accelerator Laboratory.

William C. Greene, Professor Emeritus and member of the Humanities faculty for 41 years, died on February 21 at the age of 89. In the course of his career at MIT, from 1925-66, he taught some 25 different subjects to about 6,000 students, striving to demonstrate that literature and the other arts were important to the lives of students chiefly interested in technology. He received the 1965 Gordon Y Billard Award for service to the MIT community.

Otto C. Koppen, Professor of Flight Vehicle Engineering, Emeritus, died on January 20 at the age of 90. A pioneer in both airplane design and the education of aeronautical engineers, he graduated from MIT in 1924 with a Bachelor of Science degree and became a faculty member in 1929. An authority on stability and control in aircraft, Professor Koppen won wide recognition as a designer of light, safe and easy-to-fly planes culminating in 1950 with his "helioplane," a short take-off and landing aircraft. Earlier in his career, he designed airplanes for Henry Ford, built the first fixed-rudder, easy-to-fly plane and, during World War II, worked on the design of bombers, cargo planes and gliders.

Dr. Edwin H. Land, the inventor of instant photography whose vision and financial support led to the establishment of MIT's Undergraduate Research Opportunities Program (UROP), died March 1 at the age of 80. Dr. Land envisioned a program that would allow undergraduates to become active and acknowledged members of established research teams and, to that end, established a \$1.5 million trust fund in 1968. The UROP program, now imitated world-wide, has been cited for national excellence by the US Secretary of Education. Dr. Land was a visiting Institute Professor at MIT, a position he had held since 1956.

Klauss Liepmann, a violinist and conductor who was the first full-time professor of music at MIT and founder of MIT's music program, died on July 30, 1990 at the age of 83. Professor Liepmann came to MIT in 1947 and began building a music program that now encompasses some 60 music and theater arts subjects in which more than 1,200 students are registered. He retired in 1972 as professor and director of music, but continued to teach until 1977.

Salvador E. Luria, Institute Professor, Emeritus, a pioneer in molecular biology who shared the 1960 Nobel Prize for medicine or physiology, died February 6 at the age of 78. Professor Luria, a physician and scientist, was the first to discover the phenomenon of virus host restriction in bacteria. The work, which led to the discovery of "restriction" enzymes, formed the basis of modern recombinant DNA technology. Professor Luria, a native of Italy, fled fascism in 1938 to come to the United States. He was a member of the MIT faculty in the Department of Biology from 1959 until his death. He founded the MIT Center for Cancer Research, which he directed from 1972 to 1985. In addition to his scientific work, Professor Luria was a visible and vocal member of the peace movement and was at the forefront of efforts to keep science humanistic.

Herman P. Meissner, Professor of Chemical Engineering, Emeritus, died October 24 at the age of 83. Professor Meissner came to MIT as a freshman, received both the S.B. and S.M. degrees, returned as an instructor in 1934 after taking his doctorate at the University of Frankfurt am Main, Germany, and retired in 1973 as the Lamot

duPont Professor of Chemical Engineering. He was an authority on industrial chemistry and thermodynamics.

James R. Melcher, the Julius A. Stratton Professor of Electrical Engineering and Physics and director of the Laboratory for Electromagnetic and Electronic Systems, died on January 5 at the age of 54. Widely respected for his practical applications of the principles of continuum electromechanics, Professor Melcher was considered an outstanding educator. He was inventor or co-inventor on 12 patents. Professor Melcher received the Ph.D. from MIT in 1962, the year he joined the faculty. Known for his dynamic lectures, he received the MIT Graduate Student Teaching Award in 1978. One of his books, *Continuum Electromechanics*, a graduate text published in 1981, remains the definitive text in the field.

William M. Murray, Professor of Mechanical Engineering, Emeritus, died August 14, 1990 at the age of 80. A specialist in materials stress testing, Professor Murray was a member of the mechanical engineering faculty for 33 years starting in 1940. For several years in the 1960s, he was executive officer of the department.

Augustus R. Rogowski, Professor of Mechanical Engineering, Emeritus, and former head of the Sloan Automotive Laboratory, died March 13 at the age of 85. An MIT graduate (S.M., 1928) and faculty member for 30 years, he was in charge of the automotive laboratory and all internal combustion courses for the ten years prior to his retirement in 1970. He was the author of *Elements of Internal Combustion Engines*.

Edward S. Taylor, Professor of Flight Propulsion, Emeritus, a leading figure in the development of both reciprocating and gas turbine aircraft engines, died February 2 at the age of 88. Professor Taylor was the founder and director for 22 years of MIT's Gas Turbine Laboratory, where he became recognized internationally for his work on the aircraft gas turbine engines which made possible the pure-jet, turbo-fan and turbine-driven propeller engines that power today's aircraft. He received a Bachelor of Science degree in mechanical engineering from MIT in 1924 and returned to the Institute several years later to begin his teaching career in the Sloan Automotive Laboratory for Aircraft and Automobile Engines, then headed by his brother, C. Fayette Taylor.

Bertram E. Warren, Professor of Physics, Emeritus, widely recognized for his contributions to the science of using x-rays to study the structure of matter, died June 27, the day before his 89th birthday. Professor Warren, who had three MIT degrees -- S.B., 1924; S.M., 1925; Sc.D., 1929 -- became involved in x-ray diffraction, a field then in its infancy, as a graduate student. He was appointed an instructor in the Department of Physics while studying for his doctorate and remained a member of the department until his retirement in 1967.

Glenn C. Williams, Professor of Chemical Engineering, Emeritus, died July 2 at the age of 76. Professor Williams began teaching at MIT in 1940, two years before receiving his Sc.D. from the Institute. He was an authority on missile propulsion and he headed MIT's Torpedo Fuel Laboratory during World War II. He later served as director of MIT's Fuels Research Laboratory.

David O. Wood, director of MIT's Center for Energy Policy Research and a Senior Lecturer at the Sloan School of Management, died April 28 at the age of 54. Dr. Wood was widely known for his pioneering work on the application of computer models to the economic analysis of energy problems. He held a series of government posts and came to MIT in 1976 as associate director of the MIT Energy Laboratory. He was actively involved in the teaching programs of the Sloan School and the Department of Economics.

Statistics for the Year

Registration

In 1990-91 student enrollment was 9,628, compared with 9,536 in 1989-90. This total was comprised of 4,389 undergraduates (compared with 4,307 the previous year), and 5,239 graduate students (compared with 5,229 the previous year). The international student population was 2,097, representing nine percent of the undergraduate and 33 percent of the graduate populations. These students were citizens of 103 countries. Students with permanent residence status are included with US citizens.

In 1990-91, there were 2,593 women students (1,451 undergraduate and 1,142 graduate) at the Institute, compared with 2,519 (1,460 undergraduate and 1,059 graduate) in 1989-90. In September 1990, 362 first-year women entered MIT, representing 33 percent of the freshman class of 1,085 students.

In 1990-91, there were, as self-reported by students, 1,978 minority students (1,582 undergraduate and 396 graduate) at the Institute, compared with 1,798 (1,449 undergraduate and 349 graduate) in 1989-90. Minority students included 362 Black Americans (non-Hispanic), 27 Native Americans, 427 Hispanic Americans, and 1,162 Asian Americans. The first-year class entering in September 1990 included 451 minority students, representing 42 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1990-91 included 1,107 bachelor's degrees, 1,126 master's degrees, 41 engineer's degrees, and 497 doctoral degrees -- a total of 2,771 (compared with 2,732 in 1989-90).

Student Financial Aid

During the academic year 1990-91 the undergraduate student financial aid program was again characterized by an increase in the overall need for financial aid and in the aggregate amount of grants made available. There was a small increase in the amount of Technology Loans and a substantial increase in Guaranteed Student Loans obtained from commercial sources; but awards from the Perkins Loan Program again decreased.

A total of 2,520 undergraduates who demonstrated the need for assistance (57 percent of the enrollment) received \$25,927,000 in grant aid and \$9,083,000 in student loans from all sources. The total, \$35,010,000, represents a 9 percent increase in aid compared to last year.¹

Grant assistance to undergraduates was provided by \$8,032,000 in income from the scholarship endowment, by \$1,277,000 in outside gifts, by federal grants (including

¹ Some of the figures reported last year for Fiscal Year 1989-90 have been revised since last year's President's Report was published. The revised figures appear in the Student Financial Aid Office's section of this report.

ROTC scholarships) totalling \$2,905,000, and by \$2,096,000 in direct grants from non-federal outside sources to needy students. In addition, \$11,618,000 in scholarships from MIT's unrestricted funds was provided to undergraduates, inclusive of the special program of scholarship aid to minority group students which represented \$254,000, and the MIT Opportunity Awards which accounted for about \$668,000. An additional 432 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was increased by the addition of \$6,216,000 in new funds (less than last year's increase), raising the principal of the endowment by 10 percent, to \$68,508,000.

Loans totaling \$9,083,000 were made to needy undergraduates -- a 2 percent increase from last year. Of this amount \$1,162,000 came from the Technology Loan Fund; \$2,758,000 from the Perkins Loan Program, and \$5,163,000 was obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained \$2,295,000 from the Technology Loan Fund. In addition, \$1,082,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, \$3,123,000, represents an 8 percent increase from last year's level. Graduate students obtained \$3,513,000 from outside sources under the Guaranteed Student Loan Program -- 8.5 percent more than last year. The total loaned by MIT to both graduate and undergraduate students was \$12,460,000, a 3.5 percent increase over last year.

[Note: All of the numbers reported in this section reflect awards from the academic year perspective, and so will not agree exactly with fiscal-year-based records reported by the Comptroller or the Treasurer.]

Career Services and Preprofessional Advising

In spite of tight times in many industries and in many parts of the country -- not least in Massachusetts -- few graduating students reported at year end that they were without a job. No doubt the MIT degree made a difference. No doubt other factors helped also -- the flexibility of most MIT students with regard to geographic location, and their willingness to look at other options when their first choice proves unattainable. Among their other attributes, MIT students are realists.

The number of organizations recruiting through the Careers Office was down significantly from 1989-90, dropping from 477 to 382. They included 363 private companies and nonprofit organizations and 19 government agencies. The figures are comparable to those for 1985-86, another recession year.

Students tend to scan the market less actively when they see fewer opportunities. So it was this year. The number of students having interviews dropped to 1,411 from 1,538 in 1989-90. They had a total of 9,144 interviews, down from 10,400 in 1989-90. It is likely that many students settled for employers with whom they had connections, through summer employment, previous full-time employment, or faculty contacts.

While salary offers to bachelor's and master's degree candidates in most disciplines hardly moved up at all (losing ground in real terms), salary offers to Ph.D.s rose faster than the inflation rate. The median offer in electrical engineering hit \$60,000. Among bachelor's graduates, chemical engineers fared the best. Buoyed by strong demand from the oil industry, offers at the bachelor's level in chemical engineering rose over 8 percent, to a median of \$38,400.

Preliminary statistics show the number of applicants to medical school running close to last year's total of 119. This year's candidates included 95 undergraduates, 5 graduate students, and 19 alumni. The number of undergraduates was up (from 76 in 1989-90); the number of graduate students and alumni was lower. Typically, undergraduate students enjoy a higher acceptance rate than other candidates, so the total number of MIT candidates entering medical school this fall is likely to be up from 1989-90. Last year 83 percent of MIT's undergraduate applicants were accepted.

Gifts

Gifts, grants and bequests to MIT from private donors in 1990-91 were \$110.4 million. This amount includes cash, securities, and real estate gifts totaling \$92.4 million, and \$18 million of equipment gifts. The Alumni Fund reported gifts of \$15.1 million. The Fund benefited from the continued higher level of giving from many donors who in 1990-91 responded to David Koch's \$1 million Challenge Fund which matched most increases on a one-for-two basis.

The *Campaign for the future* announced on October 22, 1987 with \$210 million in gifts and pledges, reached \$605.2 million by the end of the fiscal year toward the new goal of \$700 million by June 30, 1992. This is an increase of \$87.7 since the previous year end. The major objectives of the Campaign are support for faculty, student financial aid, academic initiatives throughout the Institute, new and renovated facilities, and unrestricted funds. The success of the Campaign to date is due in no small measure to the active involvement of so many volunteers and faculty, as well as the dedication and hard work of the staff.

Finances

As reported by the Vice President for Financial Operations and the Treasurer, the total financial operations of the Institute, including sponsored research, amounted to \$1.09 billion -- an increase of 2.1 percent over 1989-90. Education and general expenses -- excluding the direct expenses of departmental and interdepartmental research and the Lincoln Laboratory -- amounted to \$483.7 million during 1990-91, compared with \$446.9 million in 1989-90. The direct expenses of departmental and interdepartmental sponsored research on campus increased from \$220.7 million to \$229.4 million, and direct expenses of the Lincoln Laboratory's sponsored research decreased from \$396 million to \$367.7 million. Current revenues used to meet the Institute's operating expenses totaled \$1.08 billion, augmented by \$9.0 million in current gifts and \$0.3 million of other fund balances.

At the end of the 1991 fiscal year, the Institute's investments, excluding retirement funds, student notes receivable, and amounts due from educational plant, had a book

value of \$1.4 billion and a market value of \$1.77 billion compared to last year's book value of \$1.29 billion and market value of \$1.72 billion.

Physical Plant and Campus Environment

This year's efforts focused on readying the Institute for the decade ahead. Design work continued on the new biology building, which will be located on Ames Street. Excavation for the facility began in April and actual construction of the 244,000 square foot building is expected to begin early next fall. Large scale maintenance projects included roof replacements on the lower sections of the Karl Taylor Compton Laboratory and Kresge Auditorium and extensive repairs to the West Garage. The President's House was also renovated this year. A new air conditioning system was installed and the heating, electrical, and fire/safety systems were upgraded as well. In addition, major improvements for accessibility by the handicapped were incorporated in the work. Renovations to Senior House egress systems commenced this year. The project consists of enclosing stair wells, removing and/or relocating walls for direct access to fire escapes, and installing emergency lighting. Renovation of a property at 477-479 Commonwealth Avenue was expected to be completed by the beginning of the 1991 fall term. This property will house MIT's first sorority, with a capacity for up to 60 women.

The graduate student apartment complex located at 143 Albany Street, which opened last year, was dedicated to the memory of Harold "Doc" Edgerton. The design and operating concept of this facility has been enthusiastically received by the students, making it the most popular housing option in the graduate housing system.

A new five year food service contract was signed with ARA Corporation. The new agreement, entered into after a lengthy competitive process, is based on a profit and loss concept instead of the traditional cost plus fee basis, thereby providing incentive for customer service, responsiveness to changing needs, and food selections tailored specifically to MIT's needs.

This year marked the first full year of operation since completion of improvements made under Phase I of the Institute's shared savings electric rebate program. Throughout the year, rebates of over \$1.1 million were realized as a result of a reduction of approximately 18 million kilowatt hours of electricity used.

This year, Cambridge city water and sewer services cost the Institute over \$2 million, double what it cost in 1986. As the fastest growing budget item, the Institute can anticipate another increase of from 40 to 50 percent by the year 1995. However, perhaps as much as 25 percent of water use can be saved through conservation efforts. A survey to determine the extent of conservation opportunities conducted this year identified several large projects, as well as a large list of smaller potential projects that require further investigation.

Personnel Changes

CORPORATION

DEATHS

Kenneth J. Germeshausen
Life Member, Emeritus

CHANGES OF APPOINTMENT

Ralph Landau
Life Member, Emeritus

ELECTIONS

William R. Brody
Member

Alexander W. Dreyfoos, Jr.
Member

Michael M. Koerner
Member

Claudine B. Malone
Member

Christian J. Matthew
Member

DuWayne J. Peterson, Jr.
Member

Charles H. Spaulding
Life Member

Morris Tanenbaum
Member

Reginald D. Tucker
Member

William J. Weisz
Member

MEMBERS EX-OFFICIO

Peter M. Saint Germain
President
Alumni Association

His Excellency,
William F. Weld
Governor

TERMS EXPIRED

E. Milton Bevington
Member

Ernest U. Buckman
Member

Joe F. Moore
Member

Sarah A. L. Tabler
Member

FACULTY

DEATHS

John F. Elliott
Department of Materials
Science and Engineering

Edwin H. Land
Visiting Institute Professor

Salvador E. Luria
Institute Professor

James R. Melcher
Department of Electrical
Engineering and Computer
Science

Edward S. Taylor
Department of Aeronautics
and Astronautics

RETIREMENTS

Robert A. Alberty
Professor
Department of Chemistry

David J. Bloomfield
Professor
Department of Electrical
Engineering and
Computer Science

Lincoln Bloomfield
Professor
Department of Political
Science

George H. Buchi
Professor
Department of Chemistry

Stephen H. Crandall
Professor
Department of Mechanical
Engineering

Richard M. Douglas
Professor
History Section

David J. Epstein
Professor
Department of Electrical
Engineering and Computer
Science

Stephen L. Erdely
Professor
Music and Theater Arts
Section

Anthony P. French
Professor
Department of Physics

Donald R. F. Harleman
Professor
Department of Civil
Engineering

Karl Uno Ingard
Professor
Department of Physics

Frank A. McClintock
Professor
Department of Mechanical
Engineering

Harald A. T. O. Reiche
Professor
History Section

Felix M. H. Villars
Professor
Department of Physics

James Wei
Professor
Department of Chemical
Engineering

Peter A. Wolff
Professor
Department of Physics

James E. Young
Professor
Department of Physics

RESIGNATIONS

Professor

Ronald C. Davidson
Department of Physics

Henry S. Farber
Department of Economics

Leonidas J. Guibas
Department of Electrical
Engineering and
Computer Science

Daniel McFadden
Department of Economics

Associate Professor

Robert S. Gibbons
Department of Economics

Aneesh V. Manohar
Department of Physics

David H. Raulet
Department of Biology

Lloyd N. Trefethen
Department of Mathematics

Assistant Professor

Mark D. Haiman
Department of Mathematics

Ali Nadim
Department of Mathematics

Lisa B. Rofel
Anthropology/Archaeology
Program

Jeffrey M. Wooldridge
Department of Economics

PROMOTIONS

To Professor

Richard A. Andersen
Department of Brain and
Cognitive Sciences

Haruhiko Asada
Department of Mechanical
Engineering

Lawrence S. Bacow
Department of Urban
Studies and Planning

Edward A. Boyle
Department of Earth,
Atmospheric, and
Planetary Sciences

Sylvia T. Ceyer
Department of Chemistry

Joshua Cohen
Department of Linguistics
and Philosophy

Edward F. Crawley
Department of Aeronautics
and Astronautics

Alan H. Epstein
Department of Aeronautics
and Astronautics

John M. Essigmann
Division of Toxicology

Sy David Friedman
Department of Mathematics

T. Alan Hatton
Department of Chemical
Engineering

James Howe
Anthropology/Archaeology
Program

Eduardo A. Kausel
Department of Civil
Engineering

Richard K. Lester
Department of Nuclear
Engineering

W. Kendall Melville
Department of Civil
Engineering

Stephen M. Meyer
Department of Political
Science

James Paradis
Writing Program

Marc H. Raibert
Department of Electrical
Engineering and
Computer Science

Robert P. Redwine
Department of Physics

Chokyun Rha
Office of the Provost

Richard J. Samuels
Department of Political
Science

Michael S. Triantafyllou
Department of Ocean
Engineering

Edward B. Turk
Foreign Languages and
Literatures Section

Stephen A. Ward
Department of Electrical
Engineering and
Computer Science

John L. Wyatt, Jr.
Department of Electrical
Engineering and
Computer Science

To Associate Professor

Deborah G. Ancona
Sloan School
of Management

Christopher Atkeson
Department of Brain
and Cognitive Sciences

Anantaram Balakrishnan
Sloan School
of Management

E. Daniel Blankschtein
Department of Chemical
Engineering

Peter Child
Music and Theater Arts
Section

George Chryssolouris
Department of Mechanical
Engineering

Michael J. Cima
Department of Materials
Science and Engineering

Brent H. Cochran
Department of Biology

William K. Durfee
Department of Mechanical
Engineering

Kenneth A. Froot
Sloan School
of Management

Robert S. Gibbons
Department of Economics

Michael B. Giles
Department of Aeronautics
and Astronautics

Rita Bettina Goldberg
Literature Section

Ellen Hildreth
Department of Brain
and Cognitive Sciences

Mehran Kardar
Department of Physics

Thomas F. Knight, Jr.
Department of Electrical
Engineering and
Computer Science

Aneesh V. Manohar
Department of Physics

Andreas Mortensen
Department of Materials
Science and Engineering

Rishiyur S. Nikhil
Department of Electrical
Engineering and
Computer Science

Nicholas M. Patrikalakis
Department of Ocean
Engineering

Philip W. Phillips
Department of Chemistry

Daniel H. Rothman
Department of Earth,
Atmospheric, and
Planetary Sciences

David Scharfstein
Sloan School
of Management

Dwight E. Smith
Athletic Department

Steven W. Stahler
Department of Physics

John L. Tonry
Department of Physics

Richard M. Valelly
Department of Political
Science

N Venkatraman
Sloan School
of Management

Andreas H. von Flotow
Department of Aeronautics
and Astronautics

Earle R. Williams
Department of Earth,
Atmospheric, and
Planetary Sciences

Rosalind H. Williams
Writing Program

Douglas C. Youvan
Department of Chemistry

CHANGES OF APPOINTMENT

Harold L. Alexander
Lynde and Harry
Bradley Foundation
Career Development
Assistant Professor
Department of Aeronautics
and Astronautics

Ravito Bhushan
Nanyang Technological
University Career
Development
Assistant Professor
Sloan School
of Management

Alan Brody
Head of Music and Theater
Arts Section and
Professor of Theater

Claude Canizares
Director,
Center for Space Research
and Professor of Physics

Phillip L. Clay
Associate Department Head
and Associate Professor
Department of Urban
Studies and Planning

Isabelle de Courtivron
Head of Foreign Languages
and Literatures Section
and Associate Professor
of French

Jesus A. del Alamo
ITT Career Development
Assistant Professor of
Electrical Engineering
Department of Electrical
Engineering and
Computer Science

John M. Deutch
Institute Professor

Rudiger Dombusch
Associate Department
Head and Professor
Department of Economics

Mark Drela
T.A. Wilson Assistant
Professor of Aeronautics
Department of Aeronautics
and Astronautics

William Durfee
Brit and Alex d'Arbeloff
Development Associate
Professor in Engineering
Design
Department of Mechanical
Engineering

Thomas W. Eagar
Richard P. Simmons
Professor of Metallurgy
Department of Materials
Science and Engineering

Woodie Flowers
School of Engineering
Professor of Teaching
Innovation
Department of Mechanical
Engineering

Robert M. Freund
Nanyang Technological
University Senior
Associate Professor
Sloan School
of Management

Stephen C. Graves
Deputy Dean and Leaders for
Manufacturing Professor
Sloan School
of Management

Paul E. Gray
Professor of Electrical
Engineering
Department of Electrical
Engineering and
Computer Science

Steven R. Hall
Finmeccanica Career
Development Assistant
Professor
Department of Aeronautics
and Astronautics

Arnoldo C. Hax
Alfred P. Sloan Professor
of Management and Leaders
for Manufacturing Professor
Sloan School
of Management

Paul M. Healy
Nanyang Technological
University Senior
Associate Professor
Sloan School
of Management

Henry D. Jacoby
William F. Pounds Professor
Sloan School
of Management

Phillip S. Khoury
Acting Dean,
School of Humanities
and Social Science,
and Professor of History
History Section

Lionel C. Kimerling
Thomas Lord Professor
of Materials Science
and Engineering
Department of Materials
Science and Engineering

Harilaos Koutsopoulos
Mitsui Career Development
Assistant Professor
Department of Civil
Engineering

J. David Litster
Interim Associate Provost
and Vice President for
Research, Director,
Francis Bitter National
Magnet Laboratory,
and Professor of Physics

Pauline Maier
William R. Kenan, Jr.
Professor in Humanities
History Section

Roger G. Mark
Grover M. Hermann Professor
of Health Sciences and
Technology and Co-Director,
Harvard-MIT Division of
Health Sciences and
Technology

Satoru Masamune
Arthur C. Cope
Professor of Chemistry
Department of Chemistry

Robert B. McKersie
Deputy Dean and Society
of Sloan Fellows Professor
Sloan School
of Management

Albert R. Meyer
Hitachi America Professor
of Computer Science and
Engineering
Department of Electrical
Engineering and
Computer Science

Silvio Micali
Cecil H. Green
Associate Professor
of Computer Science
Department of Electrical
Engineering and
Computer Science

Joel Moses
Dean of the School
of Engineering and
Dugald C. Jackson Professor
of Computer Science
and Engineering
Department of Electrical
Engineering and
Computer Science

Alan V. Oppenheim
Distinguished Professor
of Electrical Engineering
Department of Electrical
Engineering and
Computer Science

Peter Perdue
Head of History Section
and Associate Professor
of History

William J. Qualls
Associate Professor
of Marketing
Sloan School
of Management

Donald A. Schon
Department Head
and Professor
Department of Urban Studies
and Planning

Stephen D. Senturia
Barton L. Weller Professor
of Electrical Engineering
Department of Electrical
Engineering and
Computer Science

Robert J. Silbey
Acting Department Head
and Professor of Chemistry
Department of Chemistry

Alexander H. Slocum
Visiting Assistant Professor
Department of Civil
Engineering

Ritsuko Taho
Cecil and Ida Green
Career Development
Assistant Professor
Department of Architecture

Peter Temin
Department Head
and Professor of Economics
Department of Economics

Rosalind H. Williams
Class of 1922 Career
Development Associate
Professor in Humanities
Writing Program

Gerald L. Wilson
Vannevar Bush Professor
Department of Electrical
Engineering and
Computer Science

August F. Witt
TDK Professor of Materials
Science and Engineering
Department of Materials
Science and Engineering

David N. Wormley
Associate Dean
School of Engineering
Professor of Mechanical
Engineering

J. Nicholas Ziegler
Assistant Professor of
Management
Sloan School
of Management

NEW APPOINTMENTS

Professor

Randolph N. Brooks
Professor of Naval
Architecture
Department of Ocean
Engineering

Michael Kenstowicz
Professor of Linguistics
Department of Linguistics
and Philosophy

Whitney K. Newey
Professor
Department of Economics

Charles M. Vest
Professor
Department of Mechanical
Engineering

Associate Professor

Samuel A. Bowring
Associate Professor
Department of Earth,
Atmospheric, and
Planetary Sciences

Alec Marantz
Associate Professor
Department of Linguistics
and Philosophy

Kenneth A. Oye
Associate Professor
Department of Political
Science

Jeremy C. Stein
Associate Professor
of Management
Sloan School
of Management

John R. Williams
Associate Professor
Department of Civil
Engineering

Assistant Professor

Andrew W. Alford
Assistant Professor
of Management
Sloan School
of Management

Moungi G. Bawendi
Assistant Professor
Department of Chemistry

Peter P. Belobaba
Assistant Professor
Department of Aeronautics
and Astronautics

S. Lael Brainard
Assistant Professor
of Management
Sloan School
of Management

Kenneth S. Breuer
Assistant Professor
Department of Aeronautics
and Astronautics

Roger Brooks
Assistant Professor
of Physics

Erik Brynjolfsson
Assistant Professor
of Management
Sloan School
of Management

Sheldon Chang
Assistant Professor
Department of Mathematics

James E. Chung
Assistant Professor
of Engineering
Department of Electrical
Engineering and
Computer Science

Linda G. Cima
Assistant Professor
of Chemical Engineering
Department of Chemical
Engineering and Harvard-MIT
Division of Health Sciences
and Technology

Timothy E. Dowling
Assistant Professor
Department of Earth,
Atmospheric, and
Planetary Sciences

Mary C. Fuller
Assistant Professor
of Literature
Literature Section

Louis V. Galdieri
Assistant Professor
of Literature
Literature Section

Jonathan Golden Harris
Herman P. Meissner
Class of 1929
Assistant Professor
of Chemical Engineering
Department of Chemical
Engineering

Simone Hochgreb
Assistant Professor
Department of Mechanical
Engineering

Chris Kaiser
Assistant Professor
Department of Biology

Alfredo M. Kofman
Assistant Professor
of Management
Sloan School
of Management

Kirk D. Kolenbrander
Pirelli Assistant Professor
of Electronic Materials
Department of Materials
Science and Engineering

Lee Krumholz
Assistant Professor
Department of Civil
Engineering

Hugh L. McManus
Boeing Assistant Professor
of Aeronautics and
Astronautics
Department of Aeronautics
and Astronautics

Leonard J. Morse-Fortier
Assistant Professor
Department of Architecture

James Propp
Assistant Professor
of Applied Mathematics
Department of Mathematics

Nasser Omar Rabbat
Assistant Professor
Department of Architecture

Hazel L. Sive
Assistant Professor
Department of Biology

Lynn A. Stein
Assistant Professor
of Computer Science
and Engineering
Department of Electrical
Engineering and
Computer Science

Ritsuko Taho
Assistant Professor
Department of Architecture

Stephen W. Van Evera
Assistant Professor
Department of Political
Science

Jiang Wang
Nanyang Technological
University Career
Development
Assistant Professor
Sloan School
of Management

James R. Williamson
Assistant Professor
Department of Chemistry

Boleslaw Wyslouch
Assistant Professor
of Physics
Department of Physics

Alwyn Young
Nanyang Technological
University Career
Development
Assistant Professor
Sloan School
of Management

Evan Ziporyn
Assistant Professor of Music
Music and Theater Arts
Section

Adjunct Professor

Patricia H. Hynes
Adjunct Professor
of Environmental Policy
and Planning
Department of Urban Studies
and Planning

Visiting Professor

Wlodzimierz Abramowicz
Visiting Professor
Department of Ocean
Engineering

Hannes Adomeit
Visiting Professor
Department of Political
Science

Satya N. Atluri
Jerome C. Hunsaker
Visiting Professor of
Aeronautics and Astronautics
Department of Aeronautics
and Astronautics

Marcelo Jose Cavarozzi
Visiting Professor
Department of Political
Science

David Chen
Visiting Professor
Media Arts and Sciences
Section

Peter Pin-Shan Chen
Visiting Professor
Sloan School
of Management

Ronald P. Craigie
Visiting Professor
of Aerospace Studies
Air Force Aerospace Studies

John R. Dixon
Visiting Professor
Department of Mechanical
Engineering

Michael E. Field
Visiting Professor
Naval Science

Gosta H. Granlund
Visiting Professor
Department of Mechanical
Engineering

Ahmet Gulgonen
Visiting Professor
Department of Architecture

Isom Herron
Visiting Professor
of Applied Mathematics
Department of Mathematics

Robert Charles Holub
Visiting Professor
Foreign Languages and
Literatures Section

Kai Hong
Visiting Professor
of Literature
Literature Section

Thomas P. Hughes
Visiting Professor
Program in Science,
Technology, and Society

Roger Kambour
Visiting Professor
Department of Mechanical
Engineering and Department
of Chemical Engineering

Vladimir Kamenkovich
Visiting Professor
Department of Earth,
Atmospheric, and
Planetary Sciences

Dag Kavlie
Visiting Professor
Department of Ocean
Engineering

Luise King
Visiting Professor
Department of Architecture

Laurence J. Kotlikoff
Visiting Professor
Department of Economics

Brigitte D. Lane
Visiting Professor
Foreign Languages and
Literatures Section

Shlomo Maital
Visiting Professor
Sloan School
of Management

Yuri I. Manin
Visiting Professor
Department of Mathematics

Helmut Rieder
Visiting Professor
Department of Mathematics

Shoji Shiba
Visiting Professor
Sloan School
of Management

John M. Staudenmaier
Visiting Professor
Program in Science,
Technology, and Society

Otto Steidle
Visiting Professor
Department of Architecture

Charles M. Steinberg
Visiting Professor
Center for Cancer Research

Robert Szulkin
Visiting Professor
of Literature
Literature Section

Akira Wada
Visiting Professor
Department of Civil
Engineering

Gerald T. Wellman
Visiting Professor
and Director of the
Army ROTC Program
Military Science

**Visiting Associate
Professor**

Jamel A. Akbar
Visiting Associate Professor
Department of Architecture

Amr S. Azzouz
Visiting Associate Professor
Department of Civil
Engineering

Malcolm Bloor
Visiting Associate Professor
Department of Ocean
Engineering

Michael A. Celia
Visiting Associate Professor
Department of Civil
Engineering

Zoltan Furedi
Visiting Associate Professor
of Applied Mathematics
Department of Mathematics

Christopher John Harris
Visiting Associate Professor
Department of Economics

James Jennings
Visiting Associate Professor
Department of Political
Science

Michelle Millar
Visiting Associate Professor
Department of Chemistry

Norbert G. Riedel
Visiting Associate Professor
Department of Biology

Paul A. Rudd
Visiting Associate Professor
Department of Economics

Masashi Shimizu
Visiting Associate Professor
Department of Mechanical
Engineering

Cynthia F. Simmons
Visiting Associate Professor
Foreign Languages and
Literatures Section

Nabil Tabbara
Visiting Associate Professor
Department of Architecture

Leon Van Dommelen
Visiting Associate Professor
Department of Mathematics

**Visiting Assistant
Professor**

Shmuel Ellis
Visiting Assistant Professor
of Management
Sloan School
of Management

Dara Entekhabi
Visiting Assistant Professor
Department of Civil
Engineering

Jolene Galegher
Visiting Assistant Professor
Sloan School
of Management

Sang-Gook Kim
Visiting Assistant Professor
Department of Mechanical
Engineering

Deborah J. Lucas
Visiting Assistant Professor
of Management
Sloan School
of Management

Gita Martohardjono
Visiting Assistant Professor
Foreign Languages and
Literatures Section

Walter Olbricht
Visiting Assistant Professor
Department of Mathematics

Steven E. Ostrow
Visiting Assistant Professor
History Section

Nancy S. Petersen
Visiting Assistant Professor
Department of Biology

Drazen Prelec
Visiting Assistant Professor
Department of Economics

Sabine Raffy
Visiting Assistant Professor
Foreign Languages and
Literatures Section

Joseph M. Rosen
Visiting Assistant Professor
Media Arts and Sciences
Section

Winifred B. Rothenberg
Visiting Assistant Professor
Department of Economics

Christopher Tilly
Visiting Assistant Professor
Department of Urban Studies
and Planning

Kiran Verma
Visiting Assistant Professor
Sloan School
of Management

Sherifa Zuhur
Visiting Assistant Professor
History Section

ADMINISTRATION

DEATHS

David O. Wood
Senior Lecturer
Director, Center for
Energy Policy Research
Sloan School
of Management

RETIREMENTS

Dorothy Gordon Adler
Coordinator for Alumni
Selection and Recognition
Program
Alumni Association

Allen F. Bianco
Facilities Manager
Athletic Department

Clementine I. Coblyn
Librarian
Libraries

Cesare A. Difava
Route Supervisor,
Building Services
Physical Plant

Joseph D. Gibbs
Supervisor, Paint Shop
Physical Plant

David A. Howes
Administrative Staff
Lincoln Laboratory

Jessie E. Howes
Librarian
Libraries

Elizabeth C. Hurlbert
Security Records Supervisor
Office of
Sponsored Programs

Eileen R. Kibrick
Librarian
Libraries

James F. Mahoney, Jr.
Deputy Chief for Operations
Campus Police

Marguerite A. Meyer
Administrative Assistant
Department of Materials
Science and Engineering

Walter L. Milne
Assistant to the Chairman
and to the President
Office of the President

Conor Moran
Associate Director of
Operations, Campus
Activities Complex
Physical Plant

John Rheinstejn
Administrative Staff
Lincoln Laboratory

Rebecca L. Taggart
Librarian
Libraries

Leo J. Webb
Supervisor,
Mechanical Services
Physical Plant

Lillian H. Whelpley
Advisor to
International Scholars
Public Relations Services

RESIGNATIONS

Patricia F. Ahern
Librarian
Libraries

Michelle M. Aimone
Technical Writer
Comptroller's Accounting
Office

Jill A. Appel
Senior Consultant
Network Services

John G. Arrison
Curator,
Hart Nautical Collections
Museum

Henry Barg
Director of Campaign
Operations
National Campaign Office

Gary M. C. Bean
Training Manager
Project Athena

Lisa A. Bennett
Business Manager
Endicott House

F. Michele Berrie
Applications Development
Programmer
Project Athena

Susan N. Bjorner
Librarian
Libraries

Neil J. Blaisdell
Assistant Marketing Manager
MIT Press

Andrew D. Borthwick-Leslie
Technical Writer
Project Athena

Paul E. Boutin
Systems Programmer
Project Athena

Ann P. Brazier
Manager,
Quarter Century Club
Office of Community Services

Madeline H. Brown
Acquisitions Coordinator
MIT Press

Jean Anne Bueche
Graduate Student
Administrator
Department of Chemical
Engineering

Olimpia E. Caceres-Brown
Systems Programmer
Sloan School
of Management

Christopher R. Craig
Systems Programmer
Project Athena

Ree Dawson
Assistant to the Director
Information Services

Judith F. DeCoursey
Benefits Administration
Supervisor
Personnel Office

Christopher F. Dippel
Senior Industrial
Liaison Officer
Industrial Liaison Program

Rachel Dwyer
Architectural C A D Assistant
Office of Facilities
Management Systems

Kenneth Feldman
Consultant
Information Services

Dana Friis-Hansen
Curator
List Visual Arts Center

Robin Gamer
Systems Programmer
Project Athena

James A. Gilbert
Exhibits Manager
MIT Press

Susan Giordano
Senior Analyst Programmer
Administrative Systems
Development

Rodney K. Goins
Associate Head Librarian
Libraries

Eduardo Grado
Associate Director
Admissions Office

Jane E. Grussing
Coordinator,
Graduate Alumni Programs
Alumni Association

Marcia A. Hartley
Manager of Parents Program
Alumni Association

Elizabeth Hesse
Librarian
Libraries

Richard W. Hines
Librarian
Libraries

Dena M. Hutto
Librarian
Libraries

Diane Jaroch Design Manager MIT Press	Pablo Navarro-Rivera Assistant Dean for Student Affairs and Assistant Director Office of Minority Education	Peter A. Rossetti Shift Supervisor, Building Services Physical Plant	William J. Westcott Administrative Officer Department of Mechanical Engineering
Steven M. Jones Consultant Information Services	John E. Oldham Director Office of Development Services	Susan Cronin Ruderman Assistant Director Office of Campaign Systems	Lucile N. White House Manager Housing and Food Services
Jonathan Kamens Systems Programmer Project Athena	Michael J. Parr Assistant Manager, Labor Relations Personnel Office	Alexandra B. Sabin Assistant Director of Development for School of Management Office of the Vice President for Resource Development	Barbara Whitesides Associate Director for Resource Development Center for Real Estate Development
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PROVOST

This report is intended to summarize the highlights of my activities as Provost during the 1990-1991 academic year. At the outset a few words of thanks are appropriate. I am grateful to be able to work with an outstanding group of people including the Deans, Associate Provosts, Director of Lincoln Laboratory, and Director of Libraries. I am especially appreciative of the assistance provided by Ms. Doreen Morris and Ms. Sharon Thomas during my transition to the Provost's Office. My predecessor, Institute Professor John M. Deutch, has provided an orderly and thorough assessment of the issues and status of ongoing concerns of the office, and I thank him for his prudent stewardship.

The year's activities have spanned almost every aspect of the education and research enterprise. The sections below highlight my major activities. Detailed reports from my areas of responsibility are given elsewhere in the Report to the President.

Personnel Changes

A number of people have concluded highly successful terms in key positions during 1990-1991. Coordinating the selection processes and the appointment processes for new office holders has been a major responsibility throughout the first phase of my term as Provost. Professor Kenneth A. Smith concluded his term as Vice-President and Associate Provost for Research on January 15, 1991, and Professor J. David Litster has taken on this position on an interim basis, while continuing to serve as Director of the Francis Bitter National Magnet Laboratory. Professor Gerald L. Wilson concluded his term as Dean of the School of Engineering on January 15, 1991, and Professor Joel Moses was selected as the new Dean of Engineering effective January 16, 1991. Professor Gene M. Brown concluded his term as the Dean of Science on June 30, 1991, and Professor Robert J. Birgeneau was appointed to succeed him effective July 1, 1991. Acting Dean of Humanities and Social Science, Professor Philip S. Khoury, has been selected for regular appointment to the position of Dean effective July 1, 1991. Acting Dean of Student Affairs Professor Arthur C. Smith accepted regular appointment for a two-year term commencing July 1, 1991. During the Spring of 1991, Professor John P. de Monchaux announced his intention to conclude his term as Dean of the School of Architecture and Planning during the 1991-1992 academic year, and a selection process to identify a successor has been initiated. To a person, the outgoing individuals have been supportive and constructive during an extraordinary period of change. My incoming colleagues have already demonstrated their dedicated and creative efforts on behalf of M.I.T.

Academic Computing

Project Athena came to its scheduled conclusion on June 30, 1991. This extraordinary project, a partnership between the IBM Corporation, the Digital Equipment Corporation, and M.I.T., has involved research, development, and applications relating to academic computing. M.I.T. will continue to use the Athena computing environment created by Project Athena. Through careful planning by Dean Margaret MacVicar, Professor Earll M. Murman, Director of Project Athena, Professor James D. Bruce, Vice President for Information Systems, and Professor Steven R. Lerman, Chairman of the newly formed Academic Computing Council, the service delivery aspects of Project Athena have been institutionalized in Information Systems with accountability to the Office of the Provost. Use of the Athena environment in the offering of roughly 100 subjects will continue in the Fall of 1991 and beyond in a manner transparent to the student and faculty served. Services will be maintained and enhanced as appropriate. Professor Lerman, reporting directly to the Provost, is charged with chairing the Academic Computing Council which will provide Institute-wide input regarding the academic computing programs and activities. Professor Lerman is also charged with developing new initiatives in academic computing, including research initiatives to further enhance M.I.T.'s leadership position in academic computing. The Institute is indebted to DEC and IBM for their financial, hardware, and intellectual support of Project Athena, and, with the Athena computing environment as a foundation, the Institute is well-positioned to undertake new initiatives.

Global Environment

M.I.T. can make major contributions in developing understanding of, and solutions to, global environmental problems. A faculty study chaired by Professor James Wei has drawn this conclusion based on the breadth and depth of relevant areas of research and education expertise at the Institute. Virtually all of the academic and research units could be involved, including Lincoln Laboratory, and new initiatives could draw

on relationships with the Woods Hole Oceanographic Institution with which M.I.T. is already involved in joint education and research programs. I have announced my intention to establish a Council on the Global Environment, which I will chair at the outset, to begin to coordinate and articulate M.I.T.'s programs and to assess in some detail the opportunities for new programs of research and education. The establishment of the Council has been delayed by the passing of Dr. David Wood, Director of the Center for Energy Policy Research, and the departure of Professor Wei who left to become Dean of Engineering at Princeton University. The Council on the Global Environment will commence its work in the Fall of 1991.

International Relationships

A faculty study group, commissioned by Provost John M. Deutch, and chaired by Professor Eugene B. Skolnikoff, was charged with assessing M.I.T.'s position on its current and future international relationships. The report was circulated to the faculty and widely to leaders in government, industry, and the academic sector. The study concluded that M.I.T. is an American institution by virtue of its location, student body, and base of support. At the same time, excellent educational and research programs will require significant involvement with individuals and organizations from other countries. Indeed, enhancing our students' knowledge of other cultures is deemed critical to their future success in the modern world. (My support of a program to introduce instruction in Chinese language and culture is a measure of commitment to improvement in this area.) Response to the declaration of M.I.T.'s values in undertaking international relationships has been, in the main, positive, and strong involvement with foreign institutions is concluded to be consistent with our central missions of education, discovery, and the application of discovery to the benefit of society. The international relationships currently in place will only rarely be in conflict with the conclusion that M.I.T. is an American institution with obligations to contribute to American leadership in areas vital to America's well being. Early in 1991-1992 I will review the responses to the study group report and assess the recommendations for action.

Biology Requirement and Review of General Institute Requirements and Academic Calendar

The faculty has adopted a proposal to require a subject in molecular biology of all undergraduates in the Class of 1997 (entering in the Fall of 1993). Dean Margaret MacVicar has demonstrated exceptional leadership on this issue during the past two years. Experimental subjects have been offered by the Department of Biology, and more are planned in preparation for academic year 1993-1994 and beyond. Several versions of the same subject are to be offered, in order to serve a study body having very diverse educational goals. Coupled with the new subject requirement is the call for a Presidential Committee to review the General Institute Requirements and the academic calendar. This committee is to be appointed and commence its work in the Fall of 1991. While the number of required Science Distribution subjects has been reduced from three to two, the Presidential Committee should address the tension created by introducing a substantial new core requirement into an already intense undergraduate program.

Lincoln Laboratory

Lincoln Laboratory celebrates its 40th anniversary in 1991. The activities of the Laboratory are detailed elsewhere in the Report to the President and reveal that Lincoln Laboratory remains an asset for the nation. During the first phase of my tenure as Provost, I have been acquainting myself with the programs, people, and plans of the Laboratory. I have been greatly assisted by Director Walter Morrow and Institute Professor John M. Deutch in this process. The high quality of the Laboratory is evident, and its great value to M.I.T. is also clear. A decline in the budget of the Department of Defense could adversely affect the Laboratory, but this need not be viewed as leading to loss of quality or mission. Further, research programs for Lincoln Laboratory beyond Department of Defense projects are already recognized. For example, there are impressive, substantial programs supported by the Federal Aviation Authority. Others opportunities may include ones leading to better synergism with campus programs such as cooperative research in telecommunications and global environment.

Campaign for the future

Access to adequate financial resources is critical to maintaining M.I.T.'s leadership in education and research. We have a policy of admitting undergraduates on a "need blind" basis, requiring substantial financial resources to aid the needy students who decide to attend M.I.T. Attracting and retaining the best faculty requires resources to initiate their scholarly programs leading to internationally recognized achievements. Executing sponsored research programs requires providing state of the art facilities in which to work, and, in many cases, equipment with which to work. Initiating new academic and research programs requires new resources. It is

clear that the focus on science and engineering at M.I.T. requires even more resource than other research universities of similar faculty and student size. The increased competition for support from government agencies requires greater efforts to attract support from other sources. Because of the foregoing reasons, I have adopted the goals of the *Campaign for the future* and have worked to approach individuals, industries, and foundations for support of M.I.T.'s needs and creative aspirations. I have been working closely with Ms. Cordelia Foell, Director of Academic Development, to help define my own resource development activities. Even though we expect to meet or exceed the goal of \$700 million for the *Campaign*, I see a definite continuing need to define our priorities and to work to achieve the financial base to support them. My assessment is that there are ample reasons to be optimistic about the future-- more than 90,000 successful graduates of M.I.T. to point to a few!

Research and Education Initiatives

Several academic and research initiatives have been undertaken during 1990-1991. A brief word about a few of these is appropriate.

The Academic Council has approved my proposal to establish the Faculty Fellows Program to recognize and enhance undergraduate teaching. This program will commence during 1991-1992. Selected faculty will hold the Faculty Fellow status for a period of ten years building to a steady state population of 50-75 Faculty Fellows. This group of faculty will have annual scholar allowances to enhance their educational contributions and will meet from time to time to share experiences and stimulate new ideas to improve undergraduate education at M.I.T.

A committee, chaired by Professor Ronald M. Latanision, has been exploring M.I.T.'s current activities and future possible contributions in programs relevant to pre-college education. It is clear that M.I.T. has some unique capabilities to bring to bear on this area, yet definition of an appropriate, innovative, and influential role for M.I.T. remains. It is apparent that a significant number of highly capable individuals in the M.I.T. community believe that a national leadership position in this important area is possible and desirable.

Renewal of support from the NSF for the Francis Bitter National Magnet Laboratory has been a high priority of mine and Associate Provost J. David Litster. Through patient, diligent, and effective efforts, Professor Litster has placed before the NSF a strong proposal that will benefit the national user community and allow continuity of the FBNML for the next four years. Professor Litster and his colleagues at the Lab are to be thanked for their management and response to a very difficult situation.

A rather large group of faculty have expressed interest in considering the opportunities in connection with biomedical engineering, science and technology. Professor Roger Kamm has been appointed Chairman of a planning group I have supported to assess what M.I.T. might be able to do in this area. A report on this activity is slated for early Fall, 1991.

Made in America has spawned considerable interest in follow-up activities. The Sloan Foundation, for example, has supported a study of the pharmaceutical industry led by Sloan School Professor Thomas J. Allen and Chemical Engineering Professor Charles L. Cooney. Professor Richard K. Lester has led another Sloan Foundation-supported initiative on industrial performance. Both of these programs started in 1991 represent major Sloan Foundation commitments and each involves a broad range of faculty and student interests.

Based on the success of the Leaders for Manufacturing Program, largely through the efforts of the co-directors Professors H. Kent Bowen and Thomas L. Magnanti, plans have been laid to institutionalize the program after the initial five-year experimental period. The industrial partners have participated in the planning and implementation efforts and fund raising efforts are in progress. This joint program between our School of Engineering and the Sloan School of Management stands as an excellent example of the leadership we can take to address major problem areas in education and research.

Institute Life

Unfortunately, M.I.T. is not free of sexual harassment and other forms of harassment. Recognition of this as a problem area and raising the community's understanding and consciousness to it has been an important development in Institute life. Associate Provost Jay Keyser has made important contributions in this aspect of Institute life, but much remains to be done. Facing this issue, on a regular basis, is important, especially with new students, faculty, and staff.

This past year marked the appointment of our first Martin Luther King Scholar, Dr. Henry C. McBay. The Martin Luther King Committee coordinated a week-long visit by Dr. McBay to our campus to celebrate his own accomplishments in science and education with a "festschrift" and for M.I.T. students, faculty, and staff to interact with him. Dr. McBay's charisma, insight, and enthusiasm inspired those who participated in the formal and informal events during his visit.

Academic Responsibility

Professor Sheila Widnall chairs an ad hoc faculty committee, appointed by me and the President, to address issues surrounding academic responsibilities in the conduct of educational and research programs. The committee's expectation is to engage the community in discussion of its progress report during the early Fall of 1991 and to complete its work during 1991-1992. The aims include a review of community values, an assessment of these values in light of M.I.T.'s stated policies and procedures, a comparison of guidelines of research sponsors with M.I.T.'s policies and procedures, and suggestions for new career development programs that will assist in defining academic responsibilities.

Affirmative Action Programs

M.I.T.'s leadership as a research university hinges on its ability to continue to make progress in attracting women and minority students, faculty, and staff. Good progress with the undergraduate student body is not yet reflected in our graduate student body. Specific plans are being laid with Deans Frank Perkins, Isaac Colbert, and J. J. Pitts to execute programs to highlight the opportunities in graduate school for our own minority students as well as for students at other institutions. The Academic Council has endorsed my proposed set of steps in response to the recommendations from the Equal Opportunity Committee regarding women faculty, and the Academic Council has reviewed plans to reaffirm and expand efforts to recruit minority faculty. 1991-1992 will bring new efforts to enhance the diversity of the M.I.T. community, a goal made clear to all in my areas of responsibility.

MARK S. WRIGHTON

Libraries

Certainly the year just ended was one of the more exciting and interesting ones for MIT in recent times what with the inauguration of a new president, the appointment of a new provost, and several other major changes in the administration as well as a number of national developments that kept the Institute in the media spotlight. While the annals of the Libraries for 1990/91 hardly rival these events in magnitude or moment, the year was one of substantial accomplishment and significant positive change. The Libraries' year also included a number of budget-straining events that collectively resulted in major constraints on activities and expenditures.

ROTCH LIBRARY AND OTHER SPACE PROJECTS

Efforts to improve the Libraries' physical environment -- the theme of "The Library as Place" from the 1988 strategic plan -- were greatly enhanced by the completion of the addition and renovation to the Rotch Library of Architecture and Planning. During the heat and humidity of July 1990, the collections, staff, and services housed in the original library were moved to the addition to permit the renovation phase of the project to begin. Approximately six months later, on receipt of a certificate of occupancy, the reference and periodical collections were returned and the entire facility was opened for use. Subsequently, the portion of the collection that had been in storage (about 1/3 of the total) was brought back, reversing a trend that began in 1975.

The new library has had an immediate and positive affect on patrons and staff. For the first time in decades, the collections are shelved logically and sequentially with sufficient and pleasant reading spaces. The limited access room contains all of the rare book collection in an environmentally protected and physically secure location. During the year, there was a celebration commemorating the completion of the project to restore the Charles Bulfinch professional library and the placement of these books in the limited access space. The new facility provided more efficient access to current periodicals, reference materials, folios, microforms, maps, and theses with comfortable seats, good lighting, and a fully functioning HVAC system. CD-ROM workstations and Barton terminals are located in appropriate areas with ergonomically designed furniture. The staff were delighted with their new, spacious offices, as well as with the meeting rooms and convenient access to equipment and special materials.

Publicly, the library expansion was very well received. Robert Campbell's article in the Boston Globe of April 30, 1991 was laudatory: "The Rotch is simply a gem of a building. Crisp and logical, yet expressive and poetic, it is the ideal metaphor for its contents." In an article in Progressive Architecture, in May, John Morris Dixon commented that "Schwartz Silver Architects' ingeniously compact addition to MIT's classical main building exposes a treasure of architecture and art books in a transparent vitrine." A former dean of the School of Architecture and Planning, Lawrence B. Anderson, wrote that "the architectural and technical problems appeared insoluble, but the architects have been very ingenious in dealing with these problems. Their interactions with the staff must have been productive. The project will greatly buttress the morale of the School and renew our commitment to scholarship. Everyone involved is justly proud." These remarks are a clear recognition of the tremendous success of the project that resulted from effective and harmonious collaboration and cooperation among the architects, contractors, library staff, and Institute administration.

While completion of the building project has measurably improved the quality of library service to the School of Architecture and Planning, there is a continuing need to respond to changes in the distribution of faculty and students on the campus. Most recently, the Department of Architecture has moved most of its design studios from the main campus core to buildings N51/52, about a ten minute walk from Rotch Library. There has been a series of discussions during the year aimed at developing a set of services for the studio locale. The current proposal envisions a set of visual resources and other services suited to specific studios. Online bibliographic and Athena-based reference service with some on-site librarian hours are part of the plan. Entitled the "Studio Needs Project", this program will continue to be developed as a component of the Libraries' information services study project.

RetroSpective Collection

A second major building project was completed during the past year at the Libraries' remote storage facility, the RetroSpective Collection. Use of this building as a repository for less used books and journals and for the storage of archival and manuscript collections began in 1982 when MIT acquired the structure. While structurally sound, the building has had a number of problems associated with it, most notably the lack of adequate air conditioning and humidity control and water leaks from deteriorating window seals. A major renovation took place during the year that provided new exterior aluminum cladding, air conditioning and humidity control, a refurbished and more secure office area, new electrical service, a new roof, and an upgraded entry and stairway. These improvements have provided MIT with an excellent facility for the housing of library materials. Coupled with use of the Harvard Depository in Southborough, the RSC plays a critical role in the long term storage needs of the Libraries. The project was a coordinated effort of Physical Plant, the Libraries, and several outside contractors.

Other Space-Related Activities

Following a 1989-90 study of current space utilization and possible reorganization in the technical services area in Hayden Library, the Libraries commissioned the architectural firm of Stein + Associates to undertake a formal study of how this area might be renovated to accommodate the expanded needs of the departments involved in acquisitions, cataloguing, and database maintenance. The architects worked with the Associate Director for Collection Management and Technical Services and a staff committee and produced a detailed plan that essentially re-designed the entire space. The goals that were achieved include better utilization of existing space; the creation of individual work spaces for staff that include the capacity for desktop workstations, materials storage, and ergonomically efficient furniture; better traffic and work flow; a clustering of functions that fits the organizational structure; better lighting that is also more energy-efficient; improved computer and telecommunications wiring; and flexibility to meet the changing needs of the technical services departments. With the support of the Provost, the proposal was submitted to the Committee for Review of Space Planning and was approved for implementation beginning in June 1992. The cost of the project will be funded jointly from the Institute's capital budget and the Libraries' operating budget.

In the Dewey Library, construction was completed on four new librarian offices on the first floor. This change also necessitated the shifting of the entire journals collection. The Director of Libraries was involved during the year with planning for two other libraries at MIT. One was a new library facility at the

Haystack Observatory in Westford. The second was the Burndy Library that is being moved to Cambridge in connection with the new Dibner Institute for the History of Science and Technology.

SERIAL CANCELLATIONS AND LIBRARY FINANCES

There were strong indications early in the academic year that the MIT Libraries, along with other research and academic libraries, were going to receive another budget-shattering jolt from escalating subscription prices. Anticipated increases, based on publishers' announcements and on predictions provided by a major serial vendor, ranged from 12% for domestic titles to 25% for foreign titles; the latter category accounts for 42% of MIT's subscriptions. Much of the differential was due to the weakness of the dollar abroad. The Libraries had carried out a number of cancellations projects during the past decade and had eliminated practically all duplicate subscriptions as well as a substantial number of unique titles. It was clear, however, that the combination of budget limitations and price increases would require yet another round of cancellations.

Articles were published in the Libraries' "Faculty Newsletter" and in Tech Talk alerting the community to the impending project. Letters were sent to the heads of all academic departments describing the situation and requesting their support. Library staff made an initial selection of titles for consideration that was based on usage, citation history (including by MIT faculty), price, and availability from other libraries. Department heads were contacted and arrangements were made for departmental involvement in the review. This took various forms: e.g., a list of titles circulated to the entire department; the use of a committee to review titles with library staff; the designation of individual faculty members to provide advice in specific areas. The result of the process was the identification of 1,140 titles to be cancelled effective January 1992. The table below shows the recent history of cancellation projects in the MIT Libraries.

		Titles	Dollars
1983	Boston Library Consortium project	12	\$ 600
	Chemistry Reading Room titles	26	8,700
	Duplicate titles review	168	30,000
	Von Hippel Reading Room closing	97	24,000
1986	Duplicate titles review	100	20,200
	Chemistry Reading Room closing	101	49,700
1987	Duplicate titles review	122	21,100
	Student Center Library closing	70	4,200
1988	Unique titles review	973	186,600
1991	Unique titles review	1,140	254,900
	TOTAL	2,809	\$ 600,000

The 1,140 titles cancelled in 1991 represented 14% of the total number of subscriptions held by the MIT Libraries and affected every one of the divisional and branch libraries. The Faculty Committee on the Library System participated in the design and implementation of the project and reviewed the final results.

It is clear that the continuing escalation of the cost of scholarly periodicals, especially those in technical and scientific fields but also to a considerable extent in management, economics, political science, architecture, urban planning and the humanities has caused a dramatic change in the acquisition program of the MIT Libraries as it has for other libraries serving major research universities. While publishers of research journals have begun to take serious notice of these large scale cancellations, there has been little change in the overall pattern of scholarly publishing. Long term solutions are complicated by issues of academic research and publication, finances, commercial and not for profit publisher competition, copyright, and technology. Increasingly, it appears that electronic publishing has its own set of complicated issues including pricing, and should not be viewed as an immediate solution. In the short term, libraries will have to continue to utilize a combination of cancellations, electronic access, expanded documents delivery, and resource sharing to survive and to continue to serve users' needs. At MIT, the pressures are above average because of the concentration of research in areas that are heavily journal dependent. At the same time, the journal portion of the budget can not be allowed to consume a disproportionate share. Acquisition of monographs that are critical in many areas, especially for undergraduates, online services, electronic databases, preservation, and staffing must all be protected. This is the dilemma of the research university library in the 1990's!

Funds generated by the 1991 serials cancellation project will be applied to the budget for the year beginning July 1, 1991. In addition to the primary function of maintaining the existing subscription base, cancellation funds will be used to acquire new serial titles, to cover subscriptions to online databases for the campus network, to improve the speed and coverage of document delivery activities, and to restore funds to the monographs budget that were eroded in earlier years from serials inflation.

The Libraries' fiscal situation in 1990-91 was as critical and difficult to handle as any in the past 15 years. A number of trends and events combined to create an anticipated budget shortfall of over \$500,000. The major factors were serials price inflation (19.4%) that was considerably higher than budgeted (13.4%); several large invoices that should have arrived in FY90 but actually came due in FY91; furniture and equipment costs associated with the Rotch addition; much lower than anticipated staff turnover reducing the amount of unexpended salary money available for other purposes; and reduced income from overdue fines. The last two factors are obviously connected with the general economic climate in Massachusetts. During the year the following steps were taken: all professional and support staff vacancies were frozen; no temporary staff replacements would be authorized for the remainder of the year; uncommitted funds for new serial titles, special monograph purchases, major reference titles, and collection contingencies were frozen. Beginning in mid-May, all invoices for library materials were held pending the closing of accounts in July. The Provost subsequently approved transferring the Rotch expenditures to the capital account for the building and the Libraries were able to end the year without a deficit by using special funds and by carrying over a modest amount of invoices into FY92. Based on the year's experience, estimates for unexpended salaries and fine income have been modified for the current year.

INFORMATION TECHNOLOGY AND THE LIBRARIES

A signal event took place late in the year with the signing of a contract with Marcive for the implementation of the new catalogue. This followed an extensive period of review and discussion with the Institute administration carried out

under an evaluation methodology for new information technology applications. The Libraries' project was the first major system to use this process which required extensive documentation and detailed analysis.

The schedule for the new catalogue projects public access being available early in 1992. Delivery of the database to Marcive will occur in July following the development of specifications for indexing and authority control by staff groups. Another task that was completed during the year was the design of the circulation status module. During the coming year, staff committees will be working on the design of help screens, on publicity, and on public and staff training.

A comprehensive investigation of the potentiality of installing an automated acquisitions system took place during the year under the direction of the head of the Acquisitions Department. A task force was asked to look at the possibility of using the Geac system for acquisitions since the Libraries already own the necessary software. The group was asked to analyze the benefits, costs, and impact on order preparation and workflow in public service units, in acquisitions, in fund accounting and in the systems area. The group also compared and contrasted highly centralized versus high decentralized scenarios. A final decision on implementation will be made in August 1990.

The goal of providing access to the online catalogue on a 24 hour a day basis was realized during the year. It was achieved through the use of additional disk drives acquired from Boston College in 1989. In-house and dial access to Barton after normal library hours has been steadily increasing and with the Science and Humanities libraries open 24 hours, access to the catalogue seemed both desirable and feasible.

The Systems Office experimented successfully with a local area network in the Humanities Library. While applied there to CD-ROM databases, the experience with this software is indispensable for future applications in connection with the new catalogue system.

The Libraries implemented a plan to manage and maintain its growing inventory of microcomputers, presently totalling over 150. Based on an evaluation of use, capability, and function of each unit, machines were moved to the most appropriate location. This "cascade" of microcomputers provided for optimum use and placement of newly purchased machines and the most effective use of existing ones.

The informal meetings involving staff from Information Systems, Project Athena, and the Libraries continued during the year. With the incorporation of Athena into I/S, the composition of the group now consists of the senior management of two large information services areas. Among the projects considered were the new catalogue; databases on the campus network; an online library-consultant service; possible experiments with Carnegie Mellon University's Project Mercury software; and the new Academic Computing Council on which both the Libraries and I/S are represented. The I/S - Libraries group will be focusing its attention for the next year or two on planning for the next generation of library automation at MIT.

A subgroup of the Information Systems/Project Athena/Libraries discussion group has been investigating strategies for providing access to the Medline database to MIT users via the MITnet. Medline, a bibliographic database of biomedical literature published by the National Library of Medicine, is heavily used by faculty, research, staff and students in the life sciences and other areas. It is expected that fall testing of the system will take place following acquisition of

the necessary software and data files. The project is funded jointly by Information Systems and the Libraries.

The active role taken by MIT in the Coalition for Networked Information has led to the involvement of Information Systems and the Libraries in a project being conducted by Elsevier Science Publishers to investigate electronic delivery of journals. The MIT group is working with 14 other institutions in an experiment that will look at system design, end user behavior, and intellectual property and economic issues focused on a set of journals in one major subject field, possibly materials science.

Library Locker

Design work was completed by library staff and the Athena Faculty Consultant on an online reference service module, utilizing the Athena "locker" model. Three types of library service will be available over the MIT network: (1) Electronic Bulletin Board. Information about library locations, hours of service, collections, and special bibliographies that are currently available online through "Techinfo" will be expanded and become a menu option; (2) Services. Workforms will be available to request a photocopy from the Libraries' collections, request material not at MIT, or suggest the purchase of an item not currently owned. (3) Electronic Reference Librarian. Modeled on Athena's online consultant service, this innovation will enable members of the MIT community to make online inquiries and have them answered either immediately by a staff member or queued and referred to a specialist for later response. Questions and replies will be archived and will provide a reference database that will also be available online. Combined with the existing network interface to the Barton catalogue, this panoply of services creates a sophisticated set of library services on the campus network.

RETROSPECTIVE CONVERSION

During the past year the MIT Libraries made tremendous strides in converting printed catalogue records to machine-readable format. The single largest effort was the conversion of records for monographs received between 1964 and 1974. Under contract with Online Computer Library Center (OCLC) approximately 160,000 records will be added to the database by October 1991; about 70% of the work had been completed by the end of May. Concurrently, the Bibliographic Access Services Department has begun retrospective conversion of MIT dissertations and theses covering the 1964-74 period. Another in-house project involved the conversion of records for rare books and folios in the Rotch Library that was necessitated by shelving requirements in the new building. Finally, an effort has begun for the conversion of records for books classified in the Dewey Decimal system that form the Libraries' pre-1964 collection. The first group of books to be changed are those in the field of history (900's). All of the bibliographic records created through these projects will be incorporated into the new Marcive catalogue and, in fact, over 60% were included in the database tape delivered in July 1991. The next major effort for the Libraries will be the conversion of serial records. A detailed study of methodologies and costs was initiated during the past year.

SYSTEM-WIDE DEVELOPMENTS

The Corporation Visiting Committee for the Libraries met in late October 1990 after a hiatus of over two years. The meeting was planned to coincide with the completion of the Rotch addition and renovation and although the second part of the project was yet to be completed, the Committee was able to see all of the new building. In addition, the group discussed a number of key issues including fund

raising, facilities and space, the Libraries and academic computing, the information services study, and finances. The presence of MIT's new president and just-appointed Provost provided an exceptional opportunity for information sharing and conversation.

Efforts continued during the year to define and implement a development program for the Libraries. Building on discussions with the Visiting Committee and with the Vice President for Development, a proposal was made to have a member of the staff of the Resource Development Office assigned to the Libraries on a continuing basis. Responsibility for development within the Libraries was assigned to the Senior Associate Director/Associate Director for Administration.

Relations With Other Libraries

MIT continues to participate broadly in the programs of the Boston Library Consortium. Staff are involved in a number of BLC committees as well as on the Board of Directors. In addition to continuing efforts in reciprocal access, interlibrary loan, staff development, and preservation, the BLC is engaged in a major effort to provide access to its union list of serials and to a table of contents service on the campus networks of member institutions. It is expected that members of the MIT community will have access to the union list and to the UnCover databases from Colorado Alliance of Research Libraries (CARL) Systems by the fall of 1991. The union list provides expanded access to the more than 75,000 serial titles held by member libraries and will include an online ordering module. The UnCover system is a table of contents service that offers author, title, keyword, and journal access to more than 12,000 serial titles.

Discussions were held with the senior administration of the Harvard College Library aimed at establishing a set of formal working agreements that would cover reciprocal access, borrowing, cooperative collection management, and cooperative storage of older journals. This would extend existing agreements between the MIT Libraries and several Harvard libraries; most recently an agreement was concluded with their Physics Library.

Two meetings were held between MIT Libraries' senior management and counterpart staff from the Marine Biological Laboratory/Woods Hole Oceanographic Institution Libraries. A proposal is being developed that will cover access and borrowing as well as cooperative collection development. This agreement will build on a long standing relationship between WHOI and MIT for doctoral education.

Much time and effort were expended during the year in preparation for the 14th Biennial Meeting of the International Association of Technological University Libraries scheduled for July 8-12, 1991. This will be the first time in its 40 year history that IATUL will hold a major meeting outside of Europe. MIT is a founding member of IATUL and the secretariat for its North American branch. Some 100 library directors from major technical libraries throughout the world were expected to attend.

Publications and Projects

The MIT Libraries signed an agreement with Engineering Information, Inc. (Ei) under which Ei will be provided with copies of title pages and tables of contents of newly received conferences, symposia, and seminars in technology. The information will be incorporated into Ei's Page One database that is published in CD-ROM and online versions. MIT will also serve as a document delivery source for

this program. Further discussions are scheduled that will deal with other joint activities.

The Libraries continued to participate as a member organization of the Communications Forum and in November 1990 sponsored a program on "Access to Government Scientific and Technical Information." The featured speakers were Prudence Adler from the Association of Research Libraries and Jane Bortnick from the Congressional Research Service of the Library of Congress. A session on scholarly publishing is planned for the fall of 1991.

An agreement was signed for the publication in microfilm of the Records of the Office of the MIT President, 1930-1959. The collection, covering the presidencies of Karl T. Compton and James R. Killian, will be prepared and indexed by the staff of the Institute Archives, microfilmed by the Microreproduction Laboratory, and marketed by Research Publications Inc.

The preservation microfilming project funded by the National Endowment for the Humanities continued during the year. This grant covers 39 journals in the history of technology with an emphasis on electricity and transportation. By the end of June 1991, 95% of the volumes had been through the physical inspection process and all but two titles had been sent on to the Microreproduction Laboratory for filming. The project is due for completion on December 31, 1991.

It is part of a national effort to insure the long term survival of research materials of critical importance to scholars. MIT's strengths in the history of technology also extend to monographs and a proposal was prepared during the year under the same program for the preservation microfilming of books important in the history of electricity and electrical engineering.

LIBRARY SERVICES

While external funding for an information services study was not secured, the Libraries did receive additional funding in the FY92 budget to support a scaled down version of the original plan. The study will assess the changing nature of three "bellwether" disciplines: materials science, brain and cognitive science, and management. They were chosen because of the potentialities they possess in applying the results of the study to related disciplines: physics and chemistry for materials science; biology, psychology, linguistics, philosophy, computer science, and life sciences for brain and cognitive science; and economics and political science for management. An ancillary study will be done for the design studio clientele in buildings N51/52.

The issues to be addressed include the impact of technology on the conduct of research and teaching and on information seeking behavior; differences between information strategy for teaching and research; disciplinary differences; the role of libraries and librarians in current and future information activities; and the relationship between collection policies and information service policies for the several disciplines. The study will get underway in September 1991 with a target completion date of late spring 1992.

The Psychology Liaison Program was successfully initiated in the fall of 1990. The program is designed to provide a strong library component for a large (500 students) introductory psychology course that is used by many students to fulfill part of the Institute's Writing Requirement. It links a librarian to each of the recitation sections of the course. Each librarian teaches the skills necessary for students to navigate through the source literature of psychology and through

the physical environment of the MIT Libraries. The goals established for the program by the 23 librarians who volunteered for it include gaining knowledge about the literature and how to use libraries; discriminating between popular and scholarly literature and between primary and secondary sources; and learning how and when to cite sources. The success of the venture was due to the healthy collaboration among the faculty, writing requirements staff, and librarians. Success can be measured by the increased quality of papers submitted in fulfillment of both course requirements and the writing requirement. In addition, librarians have noted a growth in sophistication of questions asked by students in the class. The program will be repeated in the fall of 1991 and a similar program will be applied to a large undergraduate course in the history of science.

The MIT Libraries hosted two sessions of research library orientation for local area high school students during the past year. Approximately 50 students from MIT's Upward Bound Program and members of the Cambridge Rindge and Latin High School Library Club were introduced to the resources of a research library --both people and materials -- and participated in a panel discussion on careers in libraries.

A full text newspaper experiment was conducted by the Computerized Literature Search Service in conjunction with the Microreproduction Laboratory. Two full text services were targeted for use: Reuters (Textline database) and DataTimes. Preliminary data gathered suggests that full text online retrieval as a method of document delivery is accepted by users as a cost effective and time saving alternative for photocopies of newsletter and newspaper articles. Objectives of the study include assessment of the speed of delivery, staff time and level and expertise required, and user acceptance as well as a comparison of full text vendors and databases in terms of cost, completeness of holdings, and ease of use.

Microreproduction Laboratory

The report of the MRL Study Group was completed in December 1990. The report reaffirmed the overall direction of the Laboratory's service plan and cited its unique and integral position in the MIT Libraries and among counterparts in other academic research libraries. The report also urged that the Laboratory form closer working relationships within the library system and at the Institute. One of the key recommendations in the report of the MRL Study Group was that the Libraries take a serious look at the feasibility of having abstracts of MIT doctoral dissertations included in University Microfilms' Dissertation Abstracts International. After careful analysis the decision was made to include these abstracts beginning with theses submitted for degrees in September 1990. The cost of including the abstract, currently \$25, will be borne by the MRL budget in anticipation of increased revenues through the sale of thesis copies. The inclusion of MIT doctoral abstracts in all of the UMI products -- online, CD-ROM, and paper -- will improve access to these important documents as well as provide greater exposure for their authors.

A second major change in MRL programs was the conversion to a new charge card system replacing the previous paper cards. The new plastic cards are much sturdier, can be sold through vending machines, and are reusable. The price of self-service quick copies made through charge cards was reduced from \$.09 to \$.08 on July 1, 1991.

The Laboratory provided support for a number of preservation microfilming projects. In addition to the NEH-sponsored project in the history of technology, the laboratory filmed 65,000 pages of late 19th and early 20th century dentistry

journals for Tufts University Health Sciences Library, in a project funded by the National Library of Medicine. Filming was also undertaken for Lincoln Laboratory, the MIT Budget Office, and the Massachusetts Historical Society. Another project involves the filming of a large collection of documents on the English Channel tunnel for the Macro-Engineering Research Group. The Laboratory also did a large volume of film duplication and enlargement for the Northeast Document Conservation Center and archival film processing for Harvard College Library.

Institute Archives

The transition in the Institute administration during the summer of 1990 required a great deal of time and effort to organize, pack, and move materials. Collections were transferred from the offices of the President, Provost, and Chairman of the Corporation, and staff worked with the new staff in these offices on file management and archival procedures. Two major records reviews were made in the Center for International Studies and the Department of Chemical Engineering. Efforts continued in conjunction with staff in other departments in preparing for the introduction of automation of bibliographic control via the RLIN system.

ORGANIZATION AND ADMINISTRATION

A reorganization of technical services resulted in the establishment of two departments in place of three. One department consists of Serials Acquisitions, Monograph Acquisitions, Gifts and MIT Publications, and Serials Cataloguing. This department is named Serials and Acquisitions Services. The other department includes Monograph Cataloguing, Database Maintenance, and Retrospective Conversion. The department is named Bibliographic Access Services.

On August 1, 1991, the title of the Associate Director position responsible for collections and technical services will be renamed. Formerly Associate Director for Collection Management and Technical Services, the title will be Associate Director for Collection Services. The position entitled Preservation and Collections Librarian will be renamed Head of Preservation and Collection Management Services.

Following a study, the Associate Director for Administration introduced a number of changes to the Libraries' serious search process for professional staff. These include the identification of minimum levels of searches; the requirement for an interim report from search committees on affirmative action prior to the interviewing of candidates; and provision for the chairing of search committees by department heads as well as by associate directors.

A Delivery Services Task Group under the leadership of the Head of Administrative Services undertook a six month review of the Libraries' mail and materials delivery activities. Recommendations covered staffing, equipment, space, the work environment, and delivery schedules.

As part of an MIT-wide effort to raise the community's consciousness about sexual harassment, following a discussion at Library Council, a small committee was appointed to review the Libraries' current situation and possible courses of action. As a result of this study, a series of sexual harassment awareness training sessions were scheduled for all supervisory personnel during the summer of 1991. The Libraries will also include information on Institute policy in this area in the orientation packets for new staff members. The Industrial Relations Library is preparing a bibliography on sexual harassment for general distribution.

Affirmative Action

During the course of the past academic year, the Libraries concluded nine national searches for new librarians and administrative staff members, and these resulted in the appointment of one new minority staff member. In addition, one member of the staff not previously recorded as an unrepresented minority was identified. Since, however, one of our current minority staff retired and another resigned, there was no overall gain in the percentage of minority staff. There are presently five minority professional staff representing 6.3% of the total group.

Major Gifts

There were several large gifts of books and journals received by the Libraries during the past year. Mrs. Elliott Adams, widow of a member of the Class of 1921, donated her husband's collection that included books in language and literature, philosophy, medicine and science, and business. Professor Emeritus of Economics Evsey D. Domar contributed additional materials in Soviet economics. From Professor Bernard Feld of Physics, the Libraries received books in physics and in arms control and disarmament. A collection emphasizing political science, history, and philosophy came from Professor William Griffiths of the Department of Political Science. Professor of Philosophy and History of Science Thomas S. Kuhn donated a significant collection in the history and philosophy of science. Professor Sheila Widnall, Department of Aeronautics and Astronautics, gave the Libraries a number of books in mechanical and aeronautical engineering.

Several new manuscript collections were received including the papers of Arthur von Hippel, Gerald Zacharias, Karl Wildes, Richard Frazier, William Allis, and Arthur Kennelly. A major addition to the papers of Harold ("Doc") Edgerton was received from his estate. Two large collections were received from retiring members of the Department of Aeronautics and Astronautics, James Mar and Theodore Pian. MIT contributions to foreign relations are described in several collections from faculty members associated with the Center for International Studies: Lincoln Bloomfield, Lucien Pye, and Ithiel de Sola Pool. Two distinguished graduates of MIT, Nathan Cohn and Malcolm Abzug, gave their papers to the Archives. The collections of David Saxon, David Baltimore, John Deutch, Bernard Feld, Paul Gray, David Middleton, Bruno Rossi, and Dirk Struik were strengthened through additions to their collections.

Personnel

Four long term staff members retired at the end of the 1990-91 academic year. Clementine Coblyn was on the staff for 16 years most recently as Hayden Circulation Librarian. Jessie Howes, science and engineering cataloguer, served for 36 years. Eileen Kibrick was on the cataloguing staff for a total of 39 years. Rebecca Taggart who served for a number of years as Head of the Barker Engineering Library and who had been on long term disability leave, formally retired as well. The Libraries are most grateful to these individuals for their dedicated and conscientious service.

Two appointments of Library Council members were made during the year. Keith Glavash, acting head of the Microreproduction Laboratory and formerly its business manager, was appointed head of the Laboratory. Theresa Tobin, acting humanities librarian and formerly associate humanities librarian, was appointed humanities librarian.

STRATEGIC PLANNING

The spring retreat of Library Council was devoted to a review of the 1988 strategic planning process and consideration of the process for the next iteration of the long range plan. The Libraries' planning effort will necessarily be linked to the campus wide process being undertaken by President Charles Vest and the Academic Council. As one step in the process, department heads were asked to include a general statement on the impact of the strategic plan on their respective areas. Some of the recurring themes that emerge from their reports include:

- The plan encouraged the concept of thinking strategically.
- It stressed the importance of the physical environment -- the Library as place.
- It emphasized outreach to the user community and the linking of library priorities to user needs.
- The plan facilitated internal communications.
- The focus on future goals was a positive element.
- There was a strong, positive effect on the quality of departmental planning.
- The inclusion of organizational values was very important and useful.
- The plan promoted the concept of "systemness".
- Streamlining and the use of reallocation of staff resources were important.

SPECIAL APPRECIATION

The accomplishments of the past year are testimony to the dedicated, resourceful, ingenious, imaginative, and hard working staff of the MIT Libraries. Whether they are carrying out their day to day responsibilities or serving on one of several committees, councils, or task forces, or individually developing new ideas or improving existing ones, the Libraries' staff continues to demonstrate why they are held in such high esteem by the MIT community, by the scholarly world in general, and by the Libraries' own administration. Their efforts are most appreciated.

The Libraries are also most grateful to the President, Provost, Senior Vice President, and other members of the administration for their continuing support and encouragement.

JAY K. LUCKER

Lincoln Laboratory

Lincoln Laboratory is operated by MIT as a Federally Funded Research and Development Center for performing research and development in advanced electronics. During the past year, agencies of the Department of Defense (DoD) -- namely, the Air Force, Army, Navy, and the Defense Advanced Research Projects Agency (DARPA) -- supplied approximately 90 percent of the Laboratory's budgetary support. The Federal Aviation Administration provided most of the non-DoD support. In fiscal year 1990 the operating budget was \$396 million, supporting the efforts of 869 professional staff, 83% of whom hold advanced degrees.

The following administrative change occurred at the Laboratory Steering Committee level during the year: Dr. Brian P. Sack became Head and Mr. David G. Woodbury became Associate Head of the Administration Division.

Technical work areas at the Laboratory include radar and optical sensors, measurements, and systems; satellite communications; signal design and processing; lasers; solid-state devices; digital technology, circuitry and data systems; tactical control systems. Unclassified highlights of several accomplishments during the past year are summarized below.

SURVEILLANCE TECHNOLOGY

Unmanned Air Vehicle Radar

Lincoln Laboratory has built a compact radar configured for a small unmanned air vehicle (UAR). This radar detects, tracks and classifies moving ground vehicles and low flying helicopters within a 15 km radius of the radar. Lincoln Laboratory has built a compact high-speed programmable processor that is part of the airborne radar system and converts tens of millions of bits per second of raw radar samples into kilobits per second of moving target reports thus drastically reducing communication requirements. Last year independent evaluators from the Army's Intelligence School operated convoys of military vehicles consisting of tanks, trucks, self-propelled howitzers and other military vehicles in both clear and rainy weather and the UAR radar operator at a ground van display was able to report the number of vehicles in the convoys, their average velocity and the mix of tracked and wheeled vehicles in real time. The success of this demonstration has led the Army to make an MTI radar a high-priority payload for the next generation of unmanned air vehicle. This year the UAR radar processing capability was increased by more than a factor of three which will support the addition of a synthetic aperture radar mode for stationary vehicle detection.

Space-Based Visible Sensor

Lincoln Laboratory has been engaged in the development of technology and techniques leading to the potential deployment of space-based visible band sensors for space surveillance. These sensors would add significant capability to the current space surveillance network. The concepts being pursued require modest optics and employ advanced CCD focal plane and signal processing technology to provide the

requisite performance. The CCD focal planes are made from high sensitivity, high pixel density CCD detector chips fabricated at Lincoln Laboratory. These chips are the best currently available for low background applications. The signal processor is designed to provide autonomous star rejection and target detection in a fault tolerant architecture appropriate for space application.

In order to demonstrate this technology in space, Lincoln Laboratory is building a visible sensor system which will be flown on the Midcourse Space Experiment satellite to be launched in 1993.

Near Earth Assessment Radar (NEAR)

Lincoln Laboratory has been engaged in the development of a new capability associated with the Haystack Radar. The major technical advances of this radar development are a wide bandwidth (2 GHz), improved real time signal processing, and low system losses through the implementation of a quasi-optical antenna feed system. The radar will serve as a proof of concept for these advanced capabilities and will be employed as a measurement tool for both enhanced radar imaging of space objects and detection and classification of small objects in near earth orbit which constitute a portion of population of Orbital Debris.

Radar Surveillance Technology Program

The Radar Surveillance Technology (RST) program is a Navy-sponsored activity aimed at improving fleet surveillance radar capability against advanced future threats. The program emphasis is in the analysis, design and demonstration of the key technologies required for an advanced radar, particularly transmitter stability to support the high level of sub-clutter visibility required, low antenna sidelobes and adaptive nulling of the antenna pattern to suppress interference. An experimental UHF radar system is being developed to demonstrate the component and system performance at a coastal test site. The components of the experimental radar, including an ultra-low sidelobe antenna, a solid state transmitter and a digital signal processor supporting sample-matrix-inversion adaptive nulling are being integrated for initial radar testing in 1992.

Optical Discrimination Technology

During the past year, Lincoln Laboratory has utilized the recently-complete long-range imaging carbon-dioxide laser radar located at Millstone Hill in Westford, MA to observe a number of targets in space. Both earth satellites and dedicated targets launched on three sounding rockets from NASA's Wallops Island Flight Facility in Virginia were employed.

The laser radar was able to observe changes in size, shape and motion of objects deployed from the sounding rockets. These successful measurements demonstrated the ability to identify and classify objects using laser radar, a capability important for ballistic missile defense.

Adaptive Optics for Atmospheric Compensation

There is considerable interest within both the military and the civilian astronomy sector in developing adaptive optics to compensate for atmospheric effects. Astronomers are interested in compensating

turbulence effects that cause a degradation in the resolution of ground-based telescopes. For astronomy at visible wavelengths the current resolution set by atmospheric turbulence is equivalent to that of a telescope of only a few tens of centimeters diameter. Adaptive optics will permit the utilization of the resolution capability of the full aperture of multi-meter telescopes.

In addition to a similar interest in adaptive optics for imaging, the military is interested in applications involving highly efficient laser propagation. When the lasers are high power, there are additional complications. Of significance is an interaction between the beam and the propagating medium, resulting in a beam-spread phenomenon called thermal blooming.

A principal goal of the Lincoln program has been to compensate for atmospheric turbulence and thermal blooming for propagated laser beams. This has been investigated in lab and field experiments and has been the subject of an intensive theoretical examination. Lincoln has developed the best computer codes anywhere for the prediction of high-power laser propagation and adaptive-optics compensation. The code has in the last year been well grounded by the experimental results.

At the present time the Lincoln capability is being applied to astronomical imaging, with the goal of transferring the technology to the civilian sector. A 241-channel system, representing the state of the art, is being installed at the Firepond site in Westford, MA to begin modifications for astronomical imaging. In the future this system is to be used at a large ground-based observatory.

SATELLITE COMMUNICATIONS

Laser Satellite Communications

The development of space qualified technology for use in satellite-satellite high data rate communication links has continued. Notable achievements include the flight qualification of a 30 milliwatt semiconductor laser transmitter, an accompanying diagnostic module (a mini-optics lab for use in space), a high bandwidth beam steering mechanism, and other precision optomechanical components.

These units are subsystems of the Laser Intersatellite Transmission Experiment (LITE) program. This experiment in high data rate coherent optical communication is designed to deliver 220 Mbps over a 23,000 mile satellite-to-satellite link. The LITE engineering model is currently being integrated and will be used for system testing.

Simultaneously, novel techniques which will reduce the size, weight and complexity of optical spaceborne communication packages are being developed. In particular, the use of optical fiber-based components permit a modularized approach to the design of such packages. In addition, technology that will be needed for very high data rate (Gbps) systems continue to be developed. These include high power (approximately 1 watt) optical sources, very wideband optical modulators, high data rate coder/decoders and efficient high bandwidth photodetectors.

EHF Satellite Communications

The EHF Satellite Communications Technology Program involves the identification, development, and demonstration of advanced concepts and technologies for future satellite communications systems. The Laboratory's FLTSAT EHF Package (FEPs) have utilized the Extremely High Frequency band (EHF; 44 GHz uplinks and 20 GHz downlinks) and spread spectrum and on-board signal processing techniques in order to provide highly robust low-data-rate (75 bps-to-2.4 Kbps per channel) links to small, perhaps mobile, terminals. The Department of Defense has incorporated the FEP's features and technologies into its Milstar system, which is being designed to carry the government's most critical strategic and tactical command and control communications.

Lincoln's technology program is currently concentrating on the complementary objectives of providing interference-resistant service at significantly higher channel data rates (> 1 Mbps) and developing components and subsystems for very efficient implementations. The technologies which are key to achieving these goals include adaptive antennas, lightweight signal generators, low-power signal processors, and reliable, efficient 20 GHz transmitters. Using ultra-lightweight waveguide and feed-horn technologies, a compact, high performance multiple-beam-antenna which can adapt its pattern to discriminate against interference sources has been realized at less than one-quarter of the weight of current implementations.

Lincoln has also developed a prototype EHF small man portable terminal (called the Advanced SCAMP) which weighs less than 30 pounds and will allow for protected single channel communications at voice rates with the FEP or Milstar systems.

AIR TRAFFIC CONTROL**Terminal Air Traffic Control**

Air traffic congestion and delay continues to grow with increases in civil air traffic. Work is underway at Lincoln Laboratory to help the FAA enhance safety, reduce controller workload, and increase capacity by developing automated planning aids for the controllers responsible for terminal airspace. This automation will help coordinate and schedule arrivals and departures and will suggest control actions for aircraft to help them comply with the schedule.

Lincoln Laboratory is working on this program in collaboration with NASA Ames Research Center and has the responsibility for detailed system engineering of an initial set of aids for a near-term operational implementation by the FAA. The Laboratory also has the responsibility for developing interfaces to the existing terminal ATC facility to extract the necessary surveillance, flight plan, and weather data and to enable the controllers to interact with the automation through existing radar display terminals. An operational evaluation of the first automation aids is being planned for the Denver airport in 1993.

Airport Surface Traffic Automation

Recent surface accidents and a rising number of runway incursion incidents at major airports have led to a renewed effort on the part of the FAA to develop automation techniques for application to the airport control tower. As part of this effort, Lincoln Laboratory is

working, under FAA sponsorship, on the multi-year Airport Surface Traffic Automation (ASTA) program. ASTA calls for the application of advanced surveillance, communications and automation techniques for the purpose of improving airport safety, reducing delays, increasing capacity and enhancing productivity. The early focus is on automatic safety systems based on surveillance from primary and beacon-based radar. Data from this electronic surveillance is subjected to a set of safety algorithms which both operate an automatic surface light system and initiate alerts for tower controllers in the event that a hazardous situation is detected. Later phases will focus on capacity issues through the development of traffic management automation integrated with other air traffic control automation systems. By the late 1990's ASTA systems are expected to be operational at 30 to 50 of the nation's busiest airports.

Precision Runway Monitor

The need for greater airport capacity has led to intense interest in the use of new technologies that can support simultaneous, independent approaches to closely spaced parallel runways in bad weather. Lincoln Laboratory has a leading role in the FAA precision runway monitor (PRM) program, which is involved in evaluation of Electronic Scan and modified Mode S secondary surveillance radars, combined with enhanced air traffic control displays, for use in monitoring approaches to closely spaced parallel runways. The Laboratory has carried out an extensive data collection and analysis program, which has indicated that both of the candidate radars can be used in this application for runways separated by as little as 3,400 feet. Additional data collection and analysis is being carried out to determine the suitability of these radars for runways separated by less than 3,400 feet.

The FAA is in the process of modifying regulations to allow simultaneous, independent approaches to parallel runways separated by 3,400 feet to 4,300 feet when monitored by the new technology radars and display systems. Lincoln is developing and testing software modifications needed for implementation of the Mode S PRM sensor and consulting with the FAA in development and implementation of an operational Electronic Scan PRM sensor.

Hazardous Weather Detection

A multi-year program in radar sensing of hazardous weather employs experimental test-bed radars with advanced signal and data processing capabilities to develop and validate systems for automatically providing weather warnings to air traffic controllers and pilots. The Laboratory-developed wind shear detection and storm motion estimation algorithms will be utilized in the Terminal Doppler Weather Radar (TDWR) to be deployed at major airports starting in 1992. Additionally the Laboratory is investigating the use of Air Surveillance Radars (ASR) and Low Level Wind Shear (LLWAS) anemometer systems to provide hazardous weather information for smaller airports.

Measurements have been carried out in a number of different locations using the test-bed radars in conjunction with other weather radars, automatic surface observation stations and instrumented aircraft. The TDWR test bed was successful in a real-time operational demonstration

of wind shear warning products at the Denver, CO, Stapleton Airport in 1988, Kansas City, MO, in 1989, and Orlando, FL in 1990-91. The FAA has commenced the production of 45 TDWR systems. The Laboratory assisted in the TDWR technical requirements specification development and proposal evaluation and is assisting in program monitoring as well as system refinement.

The Laboratory conducted successful operational tests of an ASR wind shear detection system at Orlando in 1990 and 1991, and we are investigating the integrated use of FAA and National Weather Service sensors to reduce delays and improve terminal area capacity when adverse weather occurs.

ELECTRONIC DEVICES

Solid State Mass Storage Development

A concept has been developed to efficiently utilize commercially available dRAM wafers in conjunction with laser based restructuring techniques to implement solid state mass memories with speed approaching that of dRAM, and cost approaching that of magnetic disk. As a critical component in this effort, a 20-Mbyte wafer scale memory has been demonstrated in collaboration with Micron Technologies, Inc.

Transfer of Laser Restructuring Technology

A Lincoln-developed laser restructuring facility, previously operational at Lincoln, has been established at NSA along with the associated CAD system. In addition, Restructurable Logic Arrays for rapid-turnaround ASIC customization have been used to implement several NSA test designs, and test devices have been fabricated using the Lincoln laser fusible link technology.

Superconductive Electronics

Lincoln Laboratory has been successful in producing compact, low-loss microstrip bandpass filters using thin films of superconducting $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ (YBCO) on LaAlO_3 dielectric substrates. Such filters (which have insertion losses of 0.5 dB at 77 K compared to 3 dB or more for filters of the same design made using normal metals) have been space-qualified and delivered to the Naval Research Laboratory for launch in 1992 aboard its High Temperature Superconductivity Space Experiment (HTSSE). In related work the Laboratory has produced YBCO tapped-delay-line chirp filters with 2.6-GHz bandwidth and 12-ns dispersion. A matched pair of these filters was used to demonstrate pulse compression. Superconducting YBCO microstrip antenna arrays are also under development. To improve the quality of the YBCO films, the Laboratory has developed sputtering techniques that have enabled the microwave surface resistance at 77 K to be reduced a factor of two below the prior record.

Lincoln Laboratory is a founding member of the Consortium for Superconducting Electronics, which now includes the MIT campus, the IBM Research Division, AT&T Bell Laboratories, Conductus, Boston University, Cornell University, and SUNY-Stony Brook. Efforts at these institutions are coordinated in four technical program areas: microwave networks using high-temperature superconductors; integrated circuits using low-temperature superconductors; high-temperature junctions and novel superconducting devices; and high-temperature superconducting thin-film research. In the low-temperature

superconductor area, Nb/AlO_x/Nb trilayer Josephson junctions were made on 5-inch-diameter substrates in collaboration with IBM Watson Research Center to produce record low-noise magnetometers.

Sub-0.25- μ m Optical Lithography

Since 1988, the Laboratory has been developing the technology to extend optical lithography to the 193-nm wavelength of ArF excimer lasers, which will enable integrated circuit manufacturers to pattern chips with features in the 0.15- to 0.25- μ m size range. The program has four principal technology thrusts: understanding the transmission and damage resistance of optical materials at the 193-nm wavelength and insuring a supply of material suitable for stepper fabrication; developing surface-imaging and bilayer resist processes with high resolution and contrast, good sensitivity, and low processing cost; utilizing the high photon energy to enable new processes such as all-dry resists; and constructing both steppers for use in our resist characterization work and prototypes of commercially available manufacturing steppers. To date, major progress has been made in all these areas. Fused silica adequate for use in commercial steppers has been identified. A small-field stepper has been built and used to test a variety of resists, several of which have exhibited resolution better than 0.2 μ m. In addition, a prototype production stepper with a 0.5 numerical aperture lens is being developed under subcontract to Lincoln Laboratory by SVG Lithography Systems.

ADVANCED INFORMATION PROCESSING

MX-1 Multiprocessor for Machine Intelligence Applications

A system for recognizing re-entry vehicles from sequences of radar range-doppler images was successfully coded in parallel CommonLISP and C, and executed in real time on the Lincoln MX-1 multiprocessor. In the course of this effort, the MX-1 programming environment and monitoring system proved their value in optimizing the mapping of the application onto the machine's architecture, and facilitating the rapid implementation of alternative partitioning strategies. An effort has been initiated to develop a second generation multiprocessor based on state-of-the-art microcomputer chip technology and optical interprocessor communications techniques.

Synchronous Processor

The Synchronous Processor (SP) is a SIMD (single instruction stream/multiple data stream) computer architecture developed at Lincoln Laboratory for numerically intensive, multi-dimensional signal processing applications. An early realization of the architecture, SP2, was completed in 1986 and described in the Spring 1988 issue of the Lincoln Laboratory Journal. SP2 comprised an array of 64 slave elements, each operating at 6 MOPs and containing 128K words. The combined throughput of SP2 was 384 MOPs and its total memory was 8M words.

A faster and more flexible machine, SP3, is now under construction. Physically no larger than SP2, SP3 will comprise 256 slaves for an aggregate throughput of 2.5 GOPS, and a combined memory of 256M words. SP3 is anticipated to be operational by November 1991.

In order to realize the full economic and performance potential of the SP architecture, Lincoln Laboratory has contracted for the

development of a monolithic SP slave element. This chip will combine 32-bit floating point operation with 4Mbits of on-chip memory. A fully programmable processor using 4096 such devices would provide a throughput of 200 GFLOPS in a package of 2 cubic feet and consuming about 5 KW.

Speech Topic Spotting System

Lincoln has developed an initial version of an end to end speech topic spotting system which sorts speech messages by topic, and has performed a speech message sorting experiment which is the first full test of such a system. The system includes a Hidden Markov Model wordspotter, and a topic spotter based on mutual information between the detected key word and the topic class. The experiment involved sorting among six topic scenarios using 130 key words selected from sample training messages collected using the six scenarios. Overall performance is 62% correct topic selection among the six classes, a very promising result for the first such speech topic spotting experiment.

Hybrid Hidden Markov Model/Neural Network Speech Recognition

A speech recognizer is being developed using a combination of neural network and Hidden Markov Model (HMM) techniques. Based on a comparative study of neural network classifiers, a radial basis function (RBF) classifier has been chosen to extract speech features over multiple time frames, and to provide discriminative probability scores to the HMM system. An isolated word HMM/RBF hybrid recognizer has been implemented which out performs a reference HMM recognizer on a database of highly-confusable words. Work has been initiated on using a neural network to reduce false alarm rate in a wordspotter by secondary testing on the candidate key word sets.

Artificial Neural Networks for Seismic Data Interpretation

The Machine Intelligence Technology group is developing artificial neural networks (ANNs) to improve the performance of seismic nuclear test surveillance systems. In the first year of this project we have developed ANNs that give an 86% seismic phase classification success rate compared to a 79% rate for the rule-based algorithms now employed in the DARPA/NMRO Intelligent Monitoring System (IMS). This is an error rate reduction of 33%. We now plan to install and evaluate phase recognition networks in an experimental IMS and to develop other networks that will recognize, on the basis of waveform appearance, routine mining explosions and will trigger alarms for atypical events from mining areas.

Project Athena

In collaboration with two major industrial partners, Digital Equipment Corporation and the IBM Corporation, MIT launched Project Athena in 1983 to create a computing environment that fosters significant and long-lasting improvement in the overall quality of education at MIT. In 1990-91, this major, Institute-wide initiative in academic computing completed its eighth and final year as a grant-funded experiment. It has established a successful working model of distributed computing which has had substantial effects on MIT's faculty and students and has served an increasing variety and complexity of educational needs at the Institute. Project Athena has also attracted international attention for its technical and service management developments for distributed systems and the impact these can have on higher education.

After a brief background description, this report summarizes the two major aspects of the Project, namely the development of the Athena Computing Environment and the undertaking of the Athena Educational Experiment. These sections are followed by an accounting of the impact Project Athena has had beyond MIT. The report is concluded by a summary of the recommendations of the MIT ad hoc "Committee on Academic Computation for the 1990s and Beyond" (CAC90) and the plans for the post-Athena period at MIT.

BACKGROUND

Originally funded for five years and then extended for an additional three, Project Athena began with ambitious dreams of using networked, high performance, graphic workstations to create new modes of teaching and learning. The Project had several objectives including: to support innovations in educational computing use at MIT; to provide faculty with a powerful teaching tool; to design, develop, implement, and operate a stable, secure distributed computing system of networked, heterogeneous workstation hardware; to provide software coherence in services, tools, and applications (i.e., the software works in a way that makes the differences in hardware largely invisible to the users); to ensure unlimited upward scalability of the service environment; and to offer students location-independent access to academic computing resources and to facilitate information sharing.

The first five years of the Project were dedicated to developing and implementing a new system architecture for distributed computing and for initiating over 125 curriculum development projects. Having established a largely stable and reliable system supporting a campus-wide network of workstations in academic facilities, laboratories, and student residences, and having launched many curriculum development projects, Project Athena made a shift in its emphasis during its final three years. Priority was given to using and refining the Athena Computing Environment and developed courseware which was in place. Objectives included fostering continued innovation in educational uses of computing to improve the quality of education at MIT; continuing reliable service and operations of the Athena system and further deployment of new hardware; improving stability and supportability of the Athena software suite; creating software tools to improve the human interface to Athena software; increasing the accessibility of computation and print facilities to the MIT community and accommodating a larger base of users, particularly among faculty and graduate students; and continuing the evolution of the Athena distributed computing model to accommodate personal computers in addition to UNIX workstations. Although the primary focus was on supporting MIT faculty and students and on working in concert with Athena's sponsors towards shared objectives, there was also strong interest in disseminating information about Athena and making Athena developments available to other colleges and universities.

The final year of Project Athena was focused on making a smooth transition to the post-Athena era at MIT. The guidelines were established by the report of CAC90. Activities included: planning for organizational and financial change; documenting Athena's accomplishments through videotapes, publications, and conferences; continued movement to use vendor-supplied UNIX operating systems; preparing for incorporation of DOS and Macintosh clients; addition of new software useful for a variety of educational applications; and continued support for the large base of users within the MIT community.

THE ATHENA COMPUTING ENVIRONMENT

At this time, the Athena Computing Environment is the largest distributed, truly inter-operable, yet heterogeneous, computing environment on any campus in the world. In the distributed computing model, users rely on local computers, "clients," connected to a high speed communications network, accessing "servers," thus combining the high performance of dedicated, single-user workstations with the capabilities of information sharing that usually characterize multi-user, timesharing systems. The creation of the Athena Computing Environment may be a milestone equivalent to the introduction of timesharing computing for mainframes in the 1960s.

A sophisticated, stable, powerful, and visionary system, the Athena Computing Environment makes available an array of network-based services and provides a high degree of source code portability across different machine architectures. It is sufficiently robust and flexible to have been designated as the basis for the Institute's distributed computing system well

into the next decade. It is fully extensible to all of MIT and is becoming a permanent part of MIT's computing infrastructure, a foundation on which new services and functions will be built.

The Athena system currently consists of about 1300 workstations, 80 file servers, 40 print servers, and 135 associated printers, providing 24-hour service, 365 days a year, with relatively low operating costs to about 11,000 users. About two-thirds of the workstations are located in public clusters and deployment of workstations to private offices and departmental clusters continued in 1990-91, for a total of about 40 clusters on campus. A second electronic classroom was set up, with another planned for the future.

Essential to the performance of the system has been a high speed, robust network. Until recently, MIT's network, MITnet, has consisted of a 10 Mb/sec fiber-optic token ring spine, extending the entire length of the campus. (The conversion of MITnet to FDDI, 100 Mb/sec, was completed in April.) MITnet is partitioned into 40 local area Ethernet subnets connected to the backbone through network routers. Using MITnet to connect to NEARnet (New England Academic and Research Network), the Internet, and ultimately NREN (National Research and Education Network) gives Athena users worldwide access to information. Utilizing these connections, Project Athena has exported MIT developed utilities and educational applications to other sites and began to import similar applications developed elsewhere into MIT as well. Via a series of microwave links, Athena provided services this past year to an Athena cluster of workstations at the Woods Hole Oceanographic Institute, 80 miles from the main campus. A small, test cluster was also established at the Longwood Health Sciences & Technology (HST) facility.

While most of the current systems on Athena are advanced workstations running the BSD UNIX operating system, Project Athena made significant efforts in its last year towards extending services to lower end platforms and migration to vendor-supported UNIX operating systems. DECstation 3100 client workstations were deployed running ULTRIX, the DEC UNIX operating system, and by the end of the year, IBM RS/6000 workstations, running AIX, were ready to deploy. Athena succeeded in demonstrating Macintoshes running as Athena client machines under Macintosh UNIX, A/UX. Planned extensions to integrate PC DOS and MAC OS machines made progress and will continue. Athena also endeavored to develop and deploy the IBM PS/2 running AIX as a fully functional Athena client workstation. Although substantial progress was made, several technical problems diminished the robust operation of this configuration and led to a decision not to deploy PS/2 AIX workstations in 1990-91.

The Athena Computing Environment was the subject of the First International Athena Technical Conference held on campus in April. Seventy-five organizations interested in installing the Athena model in their environments enthusiastically sent close to 200 representatives to this two-day event. The conference spawned discussions about the need for an Athena Consortium which may be initiated in the coming months. A 17-minute videotape providing an overview of the system architecture was produced and shown at the conference. It was available for distribution by the end of the academic year.

THE ATHENA EDUCATIONAL EXPERIMENT

Integral to the 8-year experiment has been the task of exploring new teaching methodologies. Over 125 faculty-led courseware development projects were funded in Athena's first five years, of which roughly 40% are an essential part of the MIT curriculum today. Five of these have won national educational software awards (four having been awarded the prestigious EDUCOM/NCRIPAL Software Awards).

Over the past few years, a critical mass of MIT faculty has become enthusiastic about the use of new technologies in their courses, utilizing the graphical, computational, and interconnected features of the Athena system. About 10% of MIT's 2000 subjects, involving all academic units, regularly give assignments on Athena. In the fall, over 100 different courses, ranging across 21 Institute departments, registered with the Project their use of Athena as an integral part of their coursework. Many others benefit from access to information and a variety of tools and services, word processing, data analysis, electronic communications, and Athena-supported applications.

Overall usage of Athena continued to increase steadily. During the fall 1990 term, about 3500 different users accessed Athena every day, with the average usage in the spring exceeding 4000 per day. By spring, virtually all undergraduates (95%), nearly three-quarters of the graduate students, and about one-third of the faculty had active Athena accounts. The Tech reported that 63% of MIT students who voted in the mid-March Undergraduate Association elections said they would be willing to pay an additional \$100 in tuition per year in order to maintain the current level of Athena services.

A number of faculty members has also shown great interest in exploring new modes of teaching and learning afforded by such developments as the Athena MUSE multimedia authoring language. Part of Athena's efforts to further the development of authoring tools, MUSE was included for the first time in an Athena system release in 1991. Developed by Project Athena's Visual Computing Group primarily to create multimedia courseware applications, MUSE is an object-oriented system that allows the integration of text, graphics (including bitmaps and pixmaps), control mechanisms, still

images, motion video, and audio. With MUSE, complex fabrics of information can easily be built, explored, and manipulated under user control. In the past year, steps were made to expand Athena's work in building applications that use multimedia, supported by more robust and lower cost systems. Work was completed to port the MUSE capability to the IBM PS/2 with AIX and the M-MOTION video card.

Also in 1990-91, Project Athena provided technical support, coupled with departmental funding, to revise and improve several early applications in light of student experience. Newer applications with greater functionality replaced older, out-dated programs. The library of commercial and third-party software available on Athena was expanded. Engineering applications from Project Northstar at Dartmouth University and Project Socrates at Cornell were ported to Athena. A scientific spreadsheet, XESS, and a mathematical symbolic manipulation program, MAPLE, were added to the suite of application software. Project Athena also worked to develop improved authoring and application prototyping tools which rely on graphics, windows, and object-oriented programming. Work was done towards the development of mechanisms for providing large amounts of writeable storage for data-intensive course applications.

Athena published "Windows on Athena, Vol. 2," a collection of 20 articles, profiling 15 curriculum development projects and including other articles describing the adoption of the Athena model on other campuses and platforms. Athena distributed a 16-minute videotape collage, produced the previous year, which presents faculty developers and students describing and demonstrating how innovative uses of computer workstations have enhanced education at MIT.

Project Athena made strides in facilitating electronic communication, both in class and out. Improvements were made in the software interface for several services and applications; students were provided with an On-Line Teaching Assistant service; On-Line Help was expanded; and an improved version of NEOS (Networked Educational On-Line System), which enables the paperless submission and return of students' work, was released. A new, electronic ombudsman, *lucy*, was instituted on the Athena system, with the involvement of representatives from several MIT offices. Users also gained on-line access to libraries; they can now connect directly to Barton, the MIT Libraries Card Catalog, or choose among four other libraries on the Internet: Boston University, HOLLIS (Harvard), MELVYL (Berkeley), and the Boston Library Consortium. A menu-based program for navigating around Athena, *dash*, was also introduced.

ATHENA'S IMPACT BEYOND THE INSTITUTE

In its eight years, Project Athena's innovations and successful developments have brought it the national and international attention of corporations, other universities, government agencies, and technological communities around the world. Last year, over 4,000 visitors to the Project's Visitors Center received briefings from Athena, tailored to their educational, technological, or managerial needs and interests. When he introduced the new NREN bill to Congress in January, Senator Albert Gore made special note of his visit, saying many of the ideas being developed at Project Athena and in other experiments could one day help students and teachers throughout the country.

Working side by side, people from MIT and Athena's vendor partners created new client-server software technology, including the X Window System, the Kerberos authentication system, the Zephyr notification service, and other system and application level programs. Through a strategy of widespread, royalty-free dissemination of Athena's developments, all this was made available to the outside world.

Since portions of this architecture have been adopted by industry, the Project has exerted significant influence in the evolution and establishment of open standards for distributed computing. There are indications that the technology of future distributed systems will be modeled after Athena. Last year, Kerberos (with Hewlett-Packard extensions) was adopted by the Open Software Foundation (OSF) for inclusion in its Distributed Computing Environment. Three other technologies have been submitted by Athena this year to OSF in response to its call for Distributed Management Environment: Moira (systems management), Zephyr, and Palladium (print services), this latter submitted together with IBM, Digital Equipment, and Hewlett-Packard.

In addition to penetrating industrial research and product development laboratories, Athena technologies have been undergoing widespread evaluation by other universities, both nationally and internationally. Seeking to integrate large numbers of workstations into their environments, many universities have adopted at least some of the key Athena system software components, either in collaboration with workstation vendors, with moderate assistance from Athena, or on their own. In the past year, these included:

Chalmers Tekniska Hogskola (Chalmers University of Technology), Gothenburg, Sweden
 Cranfield Institute of Technology, England
 Hong Kong University of Science and Technology
 Iowa State University
 Kungliga Tekniska Hvgskolan (KTH) (Royal Institute of Technology), Stockholm, Sweden
 Nanyang Technical Institute, Singapore

North Carolina State University
University of California at Berkeley
University of California at Santa Cruz
University of Maryland

Earlier, installations of Athena system software were made at Bond University in Queensland, Australia, Stanford University, and the University of Massachusetts.

REPORT OF THE COMMITTEE ON ACADEMIC COMPUTATION FOR THE 1990s AND BEYOND

During AY89, a "Committee on Academic Computation for the 1990s and Beyond" (CAC90) was formed and a report, "Computing for Education at MIT," prepared. The charge from Provost John M. Deutch to the CAC90, chaired by Professor Margaret L.A. MacVicar, Dean for Undergraduate Education, was to appraise academic computing at MIT and elsewhere, with special attention to Project Athena, and to recommend options for how MIT should proceed in the future. The twenty-member faculty committee gathered information from documents, interviews, testimony, letters, site visits, and other sources during its year of deliberations.

The results of the CAC90 study evaluating the experience of Project Athena suggested that MIT should continue to develop, implement, and support the Athena Computing Environment for advanced educational development, and further, should increase existing incentives for faculty and students to use the system for educational purposes. The Committee also found that Project Athena has had a major impact on the academic community at MIT, by facilitating communication among faculty and students through use of electronic mail and discussion forums, paperless submission and return of materials, on-line access to teaching assistants and library information, and the exchange of information through software tools and services.

In its final report, the CAC90 thus recommended that MIT:

- provide a stable, robust, and widely useful set of computational "Basic Educational Services and Tools," widely accessible from a carefully chosen small set of different platforms, over a pervasive network, in order to enhance and encourage both intellectual community and personal productivity among students, faculty and staff;
- actively encourage and support a suite of carefully targeted "Educational Development Projects," in order to improve the overall level of teaching and learning at MIT and to prepare MIT students for the coming century; and
- organize appropriate facilities, support staff, management structures, and mechanisms for assessment and review of academic computing, in order to implement these efforts effectively.

In September 1990, the Academic Council reviewed this report of the CAC90, along with a subgroup's proposed academic computing plan and budget for FY92-95. In October, Provost John Deutch sent a letter to faculty in which he wrote, in part, that Project Athena had achieved its goals. He also stated that the installed Athena system, with planned extensions to lower end platforms, had become an integral part of the MIT educational system and that it would be made an ongoing part of the MIT infrastructure. This would require financial and organizational changes, including the integration of Athena and Information Systems (IS) service functions.

Also in the fall, a strong interest continued among a number of MIT faculty, staff, and potential sponsors for a new, post-Athena endeavor, merging research, development, academic, and assessment activities towards new, innovative educational experiments. Professor Gerald Wilson, Dean of Engineering, chaired a task force to begin formulating new research activities in this area. Subsequently, a new consortium, the Center for Educational Computing Initiatives (CECI), was initiated under the direction of Professor Steven R. Lerman, former Director of Project Athena, to undertake new, externally funded research projects for educational computing.

PLANNING FOR THE POST-ATHENA ERA

Planning was initiated to facilitate a smooth transition to a post-Athena era in AY91. Professor Earl M. Murman, Director of Project Athena, and Professor James D. Bruce, Vice President for Information Systems, began work on a plan for the future provision of academic computing to MIT students, faculty and staff, given reduced resources, budgets, and staffing in 1991-92 and the coming years. The plan developed by Professors Murman and Bruce and their staffs was then presented at a faculty meeting in late February, accepted without discussion, and adopted by the administration.

As outlined in a letter to the MIT community from President Charles Vest and Provost Mark Wrighton, the objectives of this plan were to:

1. Institutionalize many of the well-developed service delivery aspects of Athena by moving them into IS;
2. Establish an academic computing director, reporting directly to the Office of the Provost;
3. Ensure continued service of over 800 Athena workstations to students in departmental and public clusters and electronic classrooms; and
4. Establish an organization from which to develop the next generation of innovative academic information technologies.

The goal of the merger with IS was to provide an academic computing environment that would build on the successes of Project Athena within the reduced budget presented by the Provost.

Three new departments created in IS are: Academic Computing Services, which provides overall coordination of academic computing, supports the faculty, and operates the Visitors Center; Computing Support Services, which manages all aspects of hardware sales, user consulting, documentation, and user training for Athena and all other currently supported computing environments; and Distributed Computing and Network Services, which provides and supports system development, application development, and network operation.

As a result of budgetary constraints, staff reductions were made in the areas of Athena operations and user support. In addition, three existing Project Athena groups were not funded by the core Institute budget: Advanced Development, the Visual Computing Group, and External Relations. (Operation of the Visitors Center, an External Relations function, was continued as part of the new Academic Computing Services group.) Nineteen full-time equivalents were laid off, in addition to the loss of six participating engineers from Athena's vendor partners. A subset of the Visual Computing Group became an integral part of CECI as the MUSE Consortium.

SUMMARY

During its last year, Athena continued its efforts to provide high quality academic computing resources to the MIT community while also preparing for its official end as a project. Based on the CAC90 report, the Athena Computing Environment is now planned to provide the computing infrastructure for the Institute for the coming decade, and Athena's service delivery functions were merged into IS to accomplish this. Outside interest in the Athena Computing Environment has fueled the possibility that an Athena Consortium may be formed. Some of the initiatives begun with Project Athena will be continued by CECI under Professor Lerman's direction, in addition to new directions undertaken by the research center. CECI's activities will focus on creating the enabling technologies that make development of educational computing applications easier and faster, encouraging new applications, and evaluating the impact on learning of educational computing.

EARLL M. MURMAN
CATHERINE AVRIL

Associate Provost for the Arts

INTRODUCTION

In its second year of operation, the Office of the Arts has continued to strengthen its support, advocacy, coordination, and facilitation of the arts at MIT, which are defined broadly to include traditional arts programs within the curriculum, professional presenting, student and student-initiated arts activities, and artistically related programs within the traditionally non-arts curriculum. The Office of the Arts (including the Council for the Arts, Arts Communication, and Special Programs, including the newly established Artist-in-Residence Program), the List Visual Arts Center, and the MIT Museum report below on an active and productive year and on changes in personnel. Immediately following are some highlights of the year's activities not associated with any one of these individual units.

Creative Arts Council (CAC): The CAC began the year with fruitful discussions on the national issue of censorship in the arts, especially as it related to the restrictions placed on grants awarded by the National Endowment for the Arts (NEA) in fiscal year (FY) 1990. The CAC voted not to have MIT recipients of NEA grants sign the required pledge as written and, after consultation with Academic Council, initiated discussions with MIT's legal counsel. Although the United States Congress voted in the autumn to drop the pledge for grants awarded in FY91, and the NEA retroactively dropped the pledge for FY90 grants, the issues of censorship remain critically important to the arts, and these were taken up by individual members and presenters of the MIT arts community, including the List Visual Arts Center (which had been singled out by Senator Jesse Helms) in its exhibit "(not so) Simple Pleasures," the MIT Museum in its striking AIDS exhibits (including "Visual AIDS III," "Memories of Eddie: Living with AIDS," and its support of the regional display of the International AIDS Quilt at MIT), various of the arts curricular programs, a Council for the Arts symposium on arts patronage, the first annual Wasserman Forum on Contemporary Art that focused this year on issues of quality and diversity in art, and a Point of View article by the Associate Provost for the Arts in *The Chronicle of Higher Education*.

A subcommittee on Post-Baccalaureate Education in the Arts at MIT (Professor Jerome Friedman, Chair; Professor Alan Brody, Professor Peter Child, Professor Ed Levine) reported on the possible future role of an interdisciplinary Fellows Program in the Arts at MIT. Such a program would build on the strengths of existing programs in the arts and focus on the particular benefits to studying the arts in the MIT environment. More traditional subject-based graduate programs could potentially grow out of such a Fellows Program while maintaining the interdisciplinary core.

A subcommittee on MIT's "1 Percent for the Arts" Policy (Professor William Porter, Chair; Dean John deMonchaux, Ms. Katy Kline, Mr. Stephen Immerman, Mr. Mark Palmgren, Mr. Ovidia R. Simha) studied the origin, history of, and changes in the Policy that dates back to at least 1968. The subcommittee drafted a procedural statement covering the execution and implementation of this policy in individual cases. The work of the subcommittee was driven in part by difficulties that had arisen in choosing art for the Stratton Student Center and Edgerton House. In the case of both buildings, new working committees are now being convened through the Office of the Arts. In the case of the new biology building, discussions have been initiated following the procedural guidelines drafted by this subcommittee that include full participation of the architect, the Planning Office, the Biology Department, and the Office of the Arts.

Spurred on by planning sessions initiated by President Charles Vest with Academic Council, the CAC discussed the role of the arts at MIT now and in 2010. These discussions have led to the drafting of a new Plan for the Arts at MIT, which is expected to be completed by December, 1991.

Arts Sections and Faculty: Among many advances and successes in the staffing and governance of arts sections, three events stand out. The Music and Theater Arts Section voted to recommend the appointment of Professor Alan Brody as Chair for three years, a recommendation that was happily accepted and enacted by Dean Philip Khoury. The Corporation voted to create a separate Visiting

Committee for the Music and Theater Arts Section, which had formerly been part of the focus of the Humanities Visiting Committee. Professor Ritsuko Taho of the Visual Arts Program was appointed to the Cecil and Ida Green Career Development Chair, the first arts faculty member to receive such an honor.

Arts facilities: The past year saw the celebratory opening of new facilities for the Visual Arts Program in N51-52, including the Berenice Abbott Photography Laboratory that was made possible by the generosity of Ronald A. Kurtz '54 MG, a member of the Council for the Arts (CAMIT). Also, faculty and students in the Dance Program benefitted from the installation of sprung floors in Walker 201 and the T-Club Lounge made possible by a collaboration of the Athletic Department, Physical Plant, and the Office of the Arts that was supported in part by a generous gift from Carl Sontheimer '37 PH. Funding for dedicated music practice rooms has been donated or pledged by CAMIT members: Anonymous and Leonard Bezark Jr. '49 MG. It is hoped that the construction of these will be completed in FY92.

UROPs in the Arts: The Undergraduate Research Opportunities Program (UROP) included a separate section on arts UROPs for the first time in its annual program booklet, increasing awareness. Thanks to a grant from the Knight Foundation, the number and diversity of arts UROPs that could be supported also increased. A generous gift from Mr. Sontheimer has matched and will continue this increased level of support for arts UROPs in FY92.

Inauguration: The Inauguration of President Vest included extraordinary arts events highlighting the work of MIT's arts students and faculty. The Inaugural Concert on the evening before the Inauguration showcased student music-making. Performances by the MIT Symphony Orchestra, MIT Concert Band, MIT Chamber Choir, and the MIT Festival Jazz Ensemble delighted a sold-out crowd at Kresge Auditorium. In addition Artists-in-Residence Karol Bennett and John McDonald performed songs for soprano and piano composed by MIT students Charles Pokorny '91 HU/Music, Alex Rigopulos '92 HU/Music, and Cynthia Harris '91 EE, and a song by Yumi Oshima '94 NU commissioned especially for the Inaugural Concert. At the Inauguration newly commissioned fanfares and processions by music faculty members Professor John Harbison, Professor Peter Child, Mr. Ed Cohen, and Professor Evan Ziporyn were premiered. One of the highlights of the Inauguration was *The Poem of Welcome* by Professor Stephen Tapscott, which was also commissioned for the occasion.

New Music Harvest: During the past year, discussions that have been ongoing for more than two years culminated in the final planning for a greater Boston festival of contemporary music November 14-17. Area institutions participating in the planning included MIT, Harvard University, Boston University, New England Conservatory, Berklee School of Music, and the Boston Symphony Orchestra. MIT will be represented in the festival with a concert on Sunday afternoon, November 17, devoted to compositions by MIT composers. The music will be performed by the contemporary music ensemble Collage conducted by David Hoose of Boston University.

Arts in traditionally non-art subjects: The arts at MIT are not relegated to arts courses. In the past year the Office of the Arts has expanded its discussions with a number of subject areas in engineering and social science in order to plan or facilitate cooperation and collaboration. These have included information-gathering meetings or initial strategy sessions with Professor William Durfee (Mechanical Engineering) concerning the new Product Design Course, Professor Paul Penfield (Electrical Engineering) concerning the Edgerton Workshop project, Professor Mark Schuster (Urban Studies and Planning) concerning federal arts funding, Professor Heather Lechtman (Center for Materials Research in Archaeology and Ethnology) concerning curatorial identification and dating of artistic materials, and Professors Roe Smith and Kenneth Keniston (Science, Technology and Society) on curatorship in science museums. In addition, alumni have spoken enthusiastically about fruitful collaborations between art and science in the past at MIT that might be considered again, such as the artistic residency of sculptor Alfred M. Duca (1960) in the department of Materials Science, who developed a new process of art casting in collaboration with faculty and students.

Fund-raising and the Campaign: The Associate Provost, with the expert help and assistance of Lucy Miller, Associate Director of Major Gifts, and Glenn Billingsley, Development Officer for the Arts, continued to take part in a large number of cultivational events on and off campus and to meet individually with prospective donors. A number of significant gifts have already been mentioned above. In addition, the List Foundation made its first contribution to a four-year pledge to support minority students in the arts. With the assistance of Clarence Williams, Special Assistant to the President, Judy J. Pitts, Associate Dean and Director, Office of Minority Education, and Ayida Mthembu, Assistant Dean for Student Affairs, the Office of the Arts has completed a draft for a List Fellows Program to support specific arts projects of one undergraduate and one graduate student each year.

The Council for the Arts increased its contributions and the proportion of contributing members to a higher level than at any time in the past five years. Total donations for FY91 totaled \$263,839, exceeding the goal of \$255,000. The number of Council donors increased from 41 in FY90 to 56 in FY91. In addition to maintaining its traditional programs (see below), the Council supported new arts facilities, and made significant contributions to the new Artist-in-Residence Program (see below) and the Office of the Arts.

With the assistance of Elizabeth T. Harding, Director, Communications Resource Development, and Celia Metcalf, Director, Design Services, the Office of the Arts published *The Arts at MIT*, which, for the first time, presents a complete picture of arts programs at the Institute. The booklet has already been used extensively in development and admissions.

Affirmative Action: The offices under the supervision of the Associate Provost for the Arts have strong representation of women on their staffs; this is due in large part to the strength of the pool of qualified women in arts-related fields. The record is quite the reverse in terms of minorities, of which there are none currently on staff. In the coming year, the Office of the Arts will formulate strengthened policies in regard to the hiring of minorities. The Office of the Arts employs seven people, six of whom are women. The List Visual Arts Center employs 15 (11.25 EFT), 11 of whom are women. The MIT Museum employs 11, six of whom are women. Of six new hires this year, four were women, replacing three men and two women (with one new hire).

One goal of the new Artist-in-Residence Program is to support multi-cultural artists and projects, in which it has been stunningly successful. Last year's program (the first) is detailed below. Of the nine artists programmed for next year, five are minorities; of these, four are women.

ELLEN T. HARRIS

Office of the Arts

Arts Communication

The second year of the Office of the Arts saw the continuation of an ongoing campaign to raise the level of awareness of the arts at MIT, both on and off campus, and to nurture and reinforce the concept of an arts *community* at MIT. The area of Arts Communication was especially involved in efforts to develop greater coordination, communication, and interdisciplinary collaboration within this community, between arts programs and the Institute at large, and between MIT and the Greater Boston arts community.

Major accomplishments in communication included the following:

--The first *Arts Map*, indicating sites at MIT where visual arts exhibitions and performances of music, theater, dance, multi-media and interdisciplinary arts currently take place at MIT, was completed and distributed. Created for MIT community members and visitors alike, the map presents a clear, aerial view of the many venues of performing and visual arts on campus, with parking lots and public transportation locations indicated. Upon its distribution in October 1990, the map has helped to increase the "accessibility factor" of MIT's arts programs and facilities, and has served a variety of public relations and communications purposes through the ArtsNet.

--*The Arts at MIT*, a comprehensive guide to curricular and co-curricular arts programs at MIT, was developed by the Office of the Arts in conjunction with the departments of Resource Development and Design Services. Created as a vehicle for admissions/recruitment, resource development and public relations, the brochure is the first publication to provide an inclusive summary of the programs, artists, and facilities that comprise the arts community at MIT.

--A selection of arts-related materials were chosen for inclusion in the "2020 Time Capsule," conceived and developed in conjunction with the inauguration of Charles M. Vest as MIT's 15th president. Items chosen included: the *Arts Map*, a reprint of the May 1 (May-At-A-Glance) Arts Page, the program from the Inaugural Concert, sheet music for a composition commissioned by Yumi Oshima '94 for the Inauguration, a copy of *The Journal of The Institute for Hacks, Tomfoolery & Pranks at MIT*, and a MIT Festival Jazz Ensemble 1990 compact disc.

--Public relations efforts and consultation were offered for "ARTTRANSITION 90" a major international conference on art, science and technology hosted by the MIT Center for Advanced Visual Studies (CAVS) under director Otto Piene. Participants included video artist Nam June Paik, holographer Vladimir Markov, and artist Paul Matisse.

Internal (MIT) arts communications included the following:

--Twenty feature Arts Pages and seven Month-At-A-Glance Arts Pages were published and distributed through Tech Talk, selected media contacts, an electronic bulletin board network, and newsletter mailings to MIT's Council for the Arts. In addition, twelve feature articles on the arts were published in Tech Talk's general spaces.

--Responding to an invitation issued to members of the MIT arts community, Sue Downing of the Theater Arts Office and Ron Platt of the List Visual Arts Center each served as guest editors of the Arts Page.

--The Arts Media Calendar went out monthly to 170 electronic and print media.

--A section on "UROP and the Arts" was included for the first time in the 1990-91 UROP Directory.

--The Office of the Arts continued its maintenance of the "Arts at MIT" bulletin board in Lobby 7.

--The "Arts Hotline," a weekly pre-recorded telephone announcement of all arts events at MIT, was maintained for its seventh year.

National press attention included:

--An editorial by Associate Provost for the Arts Ellen T. Harris in *The Chronicle of Higher Education* entitled "It Takes Practice and Serious Thought to Learn How to Dislike Art Properly," a response to the controversy surrounding the reauthorization of the National Endowment for the Arts.

--Extensive publicity for the MIT Museum's Compton Gallery exhibition, "Crazy After Calculus: Humor at MIT," including UPI and AP wire stories, a report on National Public Radio, and a full-page feature in *Newsweek*.

--Far-reaching coverage of composer Tod Machover's work at MIT's Media Lab in a number of major publications including the *New York Times*.

Local press attention included:

--A comprehensive summary of arts activities at MIT in the *Boston Globe Calendar* in an article entitled "Arts: Bargains on Campus." "The variety and quality of on-campus arts activity [at MIT] is astonishing," wrote the author. "Whether students are enrolled in music degree programs or not, interest in an enormous variety of music, dance, theatre and visual arts is keen..."

--Critical acclaim from the *Boston Globe* and the *Boston Phoenix* for exhibitions presented by the List Visual Arts Center (LVAC), and articles in each on the LVAC's new curator, Helaine Posner.

--A commendatory profile in *Art New England* on Ritsuko Taho, assistant professor in MIT's Visual Arts Program.

--Enthusiastic previews and reviews in the *Boston Globe*, *Boston Herald* and *Boston Phoenix* for a special MIT music and dance double bill featuring two premieres by Beth Soll, director of MIT's Dance Workshop, as well as works by MIT composers Peter Child, John Harbison and Evan Ziporyn performed by MIT guests artists-in-residence soprano Karol Bennett and pianist John McDonald.

Changes in personnel this year contributed to a re-evaluation of the goals and missions of Arts Communication, and staff responsibilities were modified accordingly. China Altman resigned as Director of Arts Communication in February and was succeeded by Mary L. Haller, formerly associate director of public relations at Northeastern University's Division of Performing and Visual Arts. Responsibility for the writing, design, and production of the Arts Page in Tech Talk was assumed by Senior Staff Assistants Lynn Heinemann (writer) and Susan Cohen (designer), under the supervision of the director of arts communication. Ms. Heinemann was subsequently promoted to Administrative Staff Assistant. Efforts were begun to develop a unified public relations program to expand outreach and recognition of the arts at MIT, with increased emphasis on generating external publicity.

MARY L. HALLER

Council for the Arts

The Council for the Arts, under the leadership of John W. Kunstadter '49 (Chairman) and Martin N. Rosen '62 (Vice Chairman), continued its productive and cooperative relationship with Associate Provost for the Arts, Ellen T. Harris, to integrate Council activities within the development of arts planning and programs at MIT. This year was distinguished by enthusiastic work among the standing and prize committees, a significant increase in applications to the Grants Program, and highly successful fundraising efforts. The Council's Executive Committee, six standing committees, and two prize committees conducted regular meetings throughout the year to discuss and discharge their particular responsibilities.

Council Standing Committees

Acquisitions (*Ida Ely Rubin, Chair*)

The Acquisitions Committee solicited conservation proposals from the List Visual Arts Center and the MIT Museum. In May, the Committee chairman recommended full funding for three conservation projects at the Museum: an oil portrait of William Johnson Walker by Henry Cheever Pratt (1867); a ten-section lithograph, *La Fee Electricite*, by Raoul Dufy (1953); and five hand-colored woodblock prints from *Frank Leslie's Illustrated Newspaper* (1869).

At its May meeting, the Council's Executive Committee recommended that the Acquisitions Committee be replaced by separate advisory boards for the List Visual Arts Center and the MIT Museum. Preliminary discussions on the function and composition of these committees were conducted with the directors of each institution.

Annual Meeting (*Catherine N. Stratton, Chair*)

The Eighteenth Annual Meeting of the Council for the Arts was held on November 8-9. Fifty-four Council members and guests attended the meeting.

Among the activities organized for the Annual Meeting were two panel discussions focusing respectively on significant developments within the MIT community and the national arts arena. The first forum presented an interdisciplinary faculty panel addressing "Design at MIT: Towards a More Complete Science." Serving as panelists were Woodie C. Flowers (Mechanical Engineering), Bill Hubbard, Jr. (Architecture), Heather Lechtman (Anthropology and Archeology), and Travis R. Merritt (Literature).

With arts funding under increasing scrutiny and debate nation-wide, the second forum, "Public Sphere and Private Sector: The Institutions of Arts Patronage" brought together representatives from the national philanthropic community: Karen Brosius, Director of Cultural Affairs and Special Programs, Philip Morris Company; Joan Harris, the Harris Foundation; and Anne Higonnet, Professor of Art History, Wellesley College. Topics addressing the historical role of the individual patron to the current predominance of state arts funding were presented in lively and informative papers.

Development (*Ronald A. Kurtz '54*)

Fundraising efforts this year on behalf of Council programs were marked by resounding success, with both the total number of contributing members and revenue received at their highest levels since FY87. Fifty-two Council members offered unrestricted contributions averaging \$4,304. Twenty-four non-member donors contributed an average of \$1,666 each. Designated contributions totalling \$30,540 were made by nine Council members to specific MIT arts programs.

Grants Program (Bradford M. Endicott '49)

The Grants Committee reviewed 63 applications for arts project funding from students, student groups, staff and faculty requesting a total of \$145,990. Funding was recommended for 49 projects, with grants totalling \$71,278. Six Officer's Grant applications were reviewed by the Council Director and awarded a total of \$855. A detailed report of Grants Program activity this year is available.

Among the grants awarded this year were those to the MIT Black Student Union for a year-long series of films and guest speakers to celebrate the cultural and ethnic diversity of the MIT community; the MIT Symphony Orchestra in support of a concert performance at Columbia University in New York; Hashim Sarkis, lecturer in the Department of Architecture for an exhibition, "Demarcating Lines: Urban Projects for Beirut," that will be on view at the MIT Museum and the American University in Beirut; and Beth Soll, director of MIT's Dance Workshop, in support of the creation and premiere performance of "Sanddance" a collaborative work with Boston composer Richard Cornell, based upon the Australian Aboriginal concept of "songlines."

Long-Range Planning (Alan W. Katzenstein '42; Walter A. Rosenblith, Chair)

The Long-Range Planning Committee identified two major areas for its attention and support this year: the new Artist-in-Residence Program administered by the Office of the Arts, and outreach publicity for the arts at MIT. Towards that objective, the Committee awarded funding to several projects: Dance Workshop to supplement salaries of dance company instructors and to offer a lecture-demonstration in November; List Visual Arts Center to design and produce an informational brochure on the LVAC's exhibitions; Resource Development, Office of Communications to support design and printing of "The Arts at MIT" booklet.

At its meeting in May, the Council's Executive Committee resolved that long-range planning issues were more appropriate for its own deliberations, and recommended the abolition of this committee.

Membership (Bernard G. Palitz '47, Chair)

At the conclusion of the academic year, Council membership stands at 68, excluding five *ex officio* members and one Life member. Twenty-five of the 28 members whose terms expired at the end of June were invited to renew their participation.

Seven individuals accepted new appointments to the Council from President Paul E. Gray: Roger G. Blum '41, Ruth Bowman (who served on the Council from 1974-86), Anne Hawley, Juan M. Meyer '68, Jeanne Wasserman, Elliot K. Wolk '58, and Martin E. Zimmerman '59. Four individuals were nominated to join the Council next year, pending the approval of the President of MIT, at whose invitation all Council members are appointed.

Albert P. Hildebrandt '44 resigned from the Council in September. He was appointed to the Council in 1972, and served as the chair of the Long-Range Planning Committee from 1989-1990. Malcolm L. Schoenberg '45 resigned from the Council in March. He was appointed to the Council in 1981, and served on the Grants Committee from 1985-1991.

Special ProgramsAbramowitz Memorial Lecture Series

Actor and dancer Gregory Hines was the featured speaker of the 1991 William L. Abramowitz Memorial Lecture Series on April 5. Mr. Hines has received three Tony nominations and is well-known for his film performances. His lecture and nimble demonstration on the history of tap dance in the United States delighted a full-house audience in Kresge Auditorium.

The Abramowitz Memorial Lecture Series was established by William L. Abramowitz '35 in memory of his father. Proceeds from the endowment underwrite a major performing arts event each year at MIT. Professor Alan Brody, Head of the Music and Theater Arts Section, organized this year's lecture.

Endowed Prizes and Awards

The Gyorgy Kepes Fellowship Prize was presented by Angus N. MacDonald '46 to two recipients at the Council's 18th Annual Meeting on November 9: Glorianna Davenport, Professor in Media Arts and Sciences and Stephen J. Tapscott, Professor in the Literature Program.

Following recommendations approved last year to strengthen candidate evaluation, the Kepes Fellowship Prize Committee for the first time included representatives from the Boston arts community: Peter Altman, artistic director of the Huntington Theater; Richard J. Bertman '60, partner in the architectural firm, Childs Bertman Tseckares and Casendino; and Trevor Fairbrother, Beal Curator of Contemporary Art at the Museum of Fine Arts.

The Eugene McDermott Award was presented by Ida Ely Rubin to Agnes Denes, an environmental artist from New York, at the Council's 18th Annual Meeting on November 8.

After comprehensive discussion, the McDermott Award Selection Committee resolved to review the award's objectives. With the revised criteria, the McDermott Award will continue to recognize the highest level of artistic achievement by an artist or arts advocate. The Committee will now seek candidates with estimable reputations in the creative arts communities, but whose work is less well-known beyond those spheres. Also, the award recipient will be encouraged to offer workshops, lectures, or other special programs to MIT students.

At the Awards Convocation on May 1, the Laya and Jerome B. Wiesner Student Art Awards were presented to Peter Dunn, graduate student (Aeronautics and Astronautics), for his contributions to arts communications in *The Tech*, and to the Festival Jazz Ensemble, a student performing group, for sustained achievement in music performance and long-standing popularity on campus. The Louis Sudler Prize in the Arts was awarded to Julie Schmittiel '91 (Mathematics) for excellence in theater production and stage management.

Museum Membership Programs

The Boston Museum of Fine Arts Membership Program offers free admission and discount benefits to all MIT students. Ten membership cards are also provided for the daily use of MIT staff members. MIT's enrollment in this program has been made possible by special contributions from individual Council members or through general Council support since 1980.

The Council assumed sponsorship this year of MIT's institutional membership at the Institute of Contemporary Art in Boston. MIT students receive a discount admission fee to all exhibitions, films, and special events at the ICA. Dr. Ellen Poss, an ICA trustee, had generously underwritten MIT's participation in the program for the previous three years.

MIT Symphony Orchestra New York Concert

On April 20, the MIT Symphony Orchestra, conducted by Professor David Epstein, performed Bruckner's Ninth Symphony at Columbia University's Miller Hall. This rare concert appearance by the Symphony outside of Boston was made possible by a Council for the Arts grant to support an exchange program between the MIT and Columbia student orchestras.

Wasserman Forum on Contemporary Art

The first annual Max Wasserman Forum on Contemporary Art, "Quality Control: The Challenges of Cultural Diversity," was presented on May 2 in the Wiesner Building. A panel of prominent arts leaders and scholars examined the controversy over the relationship of quality and diversity in the programs and policies of cultural and educational institutions today. W.J.T. Mitchell, editor of the journal *Critical Inquiry* and Donnelly Professor of English and Art at the University of Chicago, presented the keynote address. Panel respondents were Kimberly Camp, Director of the Experimental Gallery at the Smithsonian Institution; Trevor Fairbrother, Beal Curator of Contemporary Art at the Boston Museum of Fine Arts; and Catherine Lord, chair of the Studio

Arts Department at the University of California, Irvine and former Dean of the California Institute of the Arts. The program was developed by Mark Palmgren, director of the Council for the Arts, who served as moderator.

The Max Wasserman Forum on Contemporary Art was established in 1990 by Council member Jeanne Wasserman, in memory of her husband, MIT Class of 1935 and a founding member of the Council for the Arts. This annual forum will examine issues in contemporary visual art through an exchange of viewpoints and perspectives by scholars, artists and critics.

MARK PALMGREN

Artist-in-Residence Program

The Artist-in-Residence Program was formally established this year to enable artists in all disciplines to work directly with MIT students and faculty in both curricular and co-curricular activities. Installations, performances, or presentations by the resident artist are developed through significant interaction with students, e.g., master classes, workshops, studio critiques.

Visting artists have traditionally played an important role in the arts at MIT, with residencies serving as an integral component of programs in dance, theater, music, and the visual arts. An integrated Artist-in-Residence program was created to replace this ad hoc approach and to provide a secure source of financial and administrative support. In laying the groundwork for the program, a central concern has been its coordination with MIT's educational goals, especially in light of recent changes in the undergraduate arts curriculum. Through extensive discussions with MIT faculty and staff, the Artist-in-Residence Program has been crafted in response to specific needs and objectives.

Residencies

In its first year of operation, the Artist-in-Residence Program has helped to support an impressive variety of multicultural artists and projects, sponsored by several MIT departments or student groups.

Dean for Student Affairs

Mark Mathabane
South African writer
Lecture, "From Apartheid, South Africa, to Kaffir Boy in America, An Overview" (February)

Folk Dance Club

Zdarvets
Bulgarian Dance Workshops (January IAP)

History Section
(Sherifa Zuhur)

"Music of the Middle East"
Workshops, concerts and lectures on Arabic music (Spring semester)

Theater Arts

Sygmunt Molik
Polish actor and director
Acting workshops (January IAP)

Opera Laboratory Theater Company
Boston performance group
Artists-in-residence during fall semester
Staged high-tech version of Stravinsky's
"The Rake's Progress," in Experimental Media
Facility of the Wiesner Building (September-
February)

Visual Arts

Takura Osaka
Japanese multi-media and environmental artist
Sculpture workshops and presentation (March)

Meryl Ukeles
Performance and video artist, New York
Workshops and presentation (February)

Krzysztof Wodiczko
Public Artist, New York
Workshops and presentation (April)

A collaborative venture by the Center for Advanced Visual Studies, the List Visual Arts Center and the Visual Arts Program was explored and developed during the spring semester. Preliminary discussions have been conducted with Peter Campus, New York-based photographer, video and computer artist, to consider semester-long residency next year.

Program commitments for next year include short-term residences offered by the Music Section to pianist Patrick O'Byrne and the ROVA Saxophone Quartet. The Theater Arts Section has arranged for Decima Francis and the Roxbury Outreach Shakespeare Ensemble to be in residence for the 1991-92 academic year.

Personnel

Sara Elizabeth Wilbur was appointed as Director of Special Programs in July to oversee the Artist-in-Residence Program. Ms. Wilbur came to MIT from the Department of Education at the Boston Museum of Fine Arts. She resigned her position in March to relocate to California.

Maureen Costello, formerly director of the "Artists-in-the Schools" Program for the Cultural Educational Collaborative, a state-wide arts agency of the Massachusetts Cultural Council, will assume this position in July 1991.

MARK PALMGREN

List Visual Arts Center

The year in art was deeply affected by two interrelated conditions: widespread debate and controversy over public funding for art with overt political content, and severe and sudden cutbacks in that funding caused by the economic recession. The List Visual Arts Center, described by the Boston Globe as "arguably Boston's most exciting center for contemporary art," continued to mount an ambitious exhibition program devoted to timely, occasionally controversial, topics despite the reduction in available state and federal support for the arts. Outside funding totalled slightly over \$75,000, significantly less than in previous years. However, attendance and requests to be added to our mailing list for exhibition announcements increased noticeably. Exhibitions received substantial coverage in the local and the national print press and were frequently cited in local televised cultural coverage. Two LVAC publications won awards of merit for design excellence from the American Association of Museums; the prizewinners constitute a travelling exhibition organized by the Cedar Rapids Art Museum.

EXHIBITION PROGRAM

Eleven exhibitions were mounted in the three LVAC galleries, which addressed a variety of topics in contemporary art and culture. Each was accompanied by an illustrated publication, explanatory labels and wall text.

Student Art Loan Collection (Hayden Gallery, August 29 - September 12, 1990; lottery September 12).

The exhibition season annually is inaugurated by the display of the more than 300 contemporary graphics and photographs available by lottery for loan to MIT students and student groups for use in their living and work spaces during the academic year.

Satellite Intelligence: New Art from Boston and San Diego (Hayden and Reference Galleries, October 1 - November 18, 1990)

Through a unique organizational process (curators from the LVAC and the San Diego Museum of Contemporary Art each selected six artists from the opposite coast). The exhibition brought together painting, sculpture and installation work from the two like-sized cities, each operating just outside the orbit of the country's two primary art centers, New York and Los Angeles. Supported in part by the National Endowment for the Arts; a 36-page catalogue, with an essay by Professor Ronald Onorato, was produced.

Holography at MIT (Bakalar Gallery, October 1 - November 18, 1990)

To celebrate the fifth anniversary of the Holography Laboratory under the director of Dr. Stephen Benton, in which some of the most important developments in holography have been generated, this eclectic survey, organized by Guest Curator and holographer Betsy Connors, explored a range of recent technological innovations and featured computer-generated landscapes, objects and portraits. A 4-page illustrated brochure was produced.

(not so) Simple Pleasures (Hayden Gallery, December 7 - February 3, 1991)

The exhibition comprised paintings and sculpture by 10 artists from across the United States and Canada who use various subtle strategies to embed potent, often political, content within a deceptively attractive object or image. A 32-page illustrated catalogue was produced.

The Missing Picture: Alternative Contemporary Photography from the Soviet Union (Reference Gallery, December 7 - February 3, 1991)

Guest Curator John P. Jacob selected four younger Russians who work at the forefront of experimental Soviet photography. Alexi Shulgin's appropriations of found images from the 1950s; Vladimir Kupreanov's deadpan "heroic" portraiture, Maria Serebrejekova's conceptual landscapes and still lifes and Ilya Piganov's text and image combinations were included.

The Missing Picture: Boris Michailov (Bakalar Gallery, December 7 - February 3, 1991)

The first exhibition in the West of this Ukrainian artist, considered the father of avant-garde Soviet photography surveyed several decades of his production, including handpainted photographic albums and erotica. A 48-page catalogue of the two related Soviet photography exhibitions was published and won an award for design excellence from the American Association of Museums; the two exhibitions will travel during 1991-1992 to other museums in the US. These exhibitions were supported in part by the Trust for Mutual Understanding and the Soros Foundation.

Juan Francisco Elso Padilla (Hayden Gallery, February 23 - April 14, 1991)

Six highly charged works in wood, mud, straw and basket material constituted the first US exhibition of the late Cuban sculptor, whose evocative objects in both very small and very large scale are a highly personal blend of secularism, mysticism and magic and embody an attempt to identify and express a specific Latin-American mythology. The artist's first English-language catalogue, a 12-page illustrated publication with an essay by the Latin-American artist and critic Luis Camnitzer, was co-produced with the Museo Carillo Gil in Mexico City.

Robert Arneson: The Jackson Pollock Series (Reference Gallery, February 23 - April 14, 1991)

In 1982 this celebrated San Francisco-based ceramicist took up the theme of the life, work, death and myth of the famous Abstract-Expressionist painter; the exhibition included large portrait busts and heads of Pollock, recreations of his final car crash and a larger than life-sized, three-dimensional interpretation of Pollock's major painting, *Guardians of the Secret*. A 4-page explanatory pamphlet was prepared.

Barbara Broughel: Storytelling Chairs (Bakalar Gallery, February 23 - April 14, 1991)

Eight Early American chairs were subverted, doctored and decorated by this New York-based sculptor long interested in devising artistic symbols of colonial exploitation. Her insertions and substitutions deftly referred to the important, if under-acknowledged contribution of Native American law, medicine and agriculture to early American history. The colorful illustrated publication received an award for design excellence from the American Association of Museums.

suitCase Studies: Tourisms (Hayden Gallery, May 3 - June 30, 1991)

The New York-based architects Elizabeth Diller and Ricardo Scofidio constructed a dramatic installation on the theme of "constructed tourism" by suspending 50 open suitcases each containing the contrived memorabilia of an historic bedroom or battlefield from each state. The installation was a component of the prestigious series *Architecture Tomorrow* organized by the Walker Art Center in Minneapolis. The exhibition at MIT was partially supported by the LEF Foundation.

Mark Tansey: Art and Source (Reference Gallery, May 3 - June 30, 1991)

This mid-career, New York painter showed four of his characteristic monochromatic, pseudo-realist oils which constitute complex meditations on the interplay of reality, illusion and representation. Preparatory works and source materials, ranging from magazine photos, news clippings, photocopies and drawings illuminated his working process. The exhibition was organized by the Seattle Art Museum.

Warren Neidich: Historical In(ter)ventions (Bakalar Gallery, May 3 - June 30, 1991)

Neidich's work examines not only the contradictions of the American past but also the ways in which the media shape and distort the perception of current events. His "Time Pods" condensed work from four earlier photographic series which delved into the contradictions of the American past. Two new works were created for this exhibition: "Nuclear Family," a video installation about the apathetic acceptance of television, and "Collaborative Memory", a modular, wall-mounted sculpture investigating olfactory and visual memory. An illustrated catalogue with an essay by David Joselit was published.

Against Nature: Japanese Art in the 80's, organized jointly by the LVAC and the Grey Art Gallery at New York University, completed its eight-stop international tour with a showing at the Institute of Contemporary Art, Nagoya, Japan. Opening in June 1989 at the San Francisco Museum of Modern Art, it had subsequently

been seen at the Akron Art Museum; LVAC; Seattle Art Museum; Contemporary Art Center, Cincinnati; Grey Art Gallery; and Contemporary Arts Museum, Houston.

EDUCATIONAL PROGRAM

A variety of educational activities were planned around the exhibitions. In addition to gallery talks and tours by the respective curators, we were fortunate to be able to enlist many of the artists to speak on their work. Shulgin, Kuprejanov, Serebrejekova and Piganov led a lively walkthrough of the Soviet photography exhibitions; Barbara Broughel and Diller and Scofidio both spoke to large and attentive audiences in their exhibition spaces. For *Satellite Intelligence* two San Diego artists (Jean Lowe and Anne Mudge) and San Diego Curator Lynda Forsha, together with Boston artists Mags Harries and Gerry Bergstein, participated in a lively roundtable, led and moderated by LVAC director Katy Kline. Outside lecturers Dr. Stephen Benton from MIT's Media Laboratory and Patterson Sims, director for exhibitions and collections at the Seattle Art Museum spoke on the *Holography* and *Mark Tansey* exhibitions respectively. Exhibitions and collection tours by the director and curator were arranged for numerous groups ranging from college and art school courses to adult education groups to museum trustee and collector's groups from around the country.

PERSONNEL

In December, 1990 Dana Friis-Hansen resigned as curator to relocate to Japan. We were most fortunate to be able to hire Helaine Posner, previously director of the gallery at the University of Massachusetts at Amherst and then Chief Curator at the National Museum of Women in the Arts in Washington, D.C. who joined the staff on March 1, 1991. Erika Deutsch, LVAC secretary since 1985, resigned in August, 1990 and was replaced by Cynthia Cole, whom we managed to woo away from MIT's Plasma Fusion Center.

ACQUISITIONS

The following works were acquired through either gift or purchase during the 1990-1991 academic year:

Permanent Collection

Georgy Kepes, *Untitled (Roma 1961)*, 1961, oil and sand on canvas. Gift of C. Fayette Taylor, MIT '29.

Harry Bertoia, *Untitled Study for Wall Piece*, n.d., lithograph on rice paper. Gift of C. Fayette Taylor, MIT '29.

Leonard Brooks, *Souvenir Marseillaise*, 1971, collage on paper. Gift of C. Fayette Taylor, MIT '29.

Lily Saarinen, *Untitled (Eagle)*, 1963, ink on vellum. Gift of C. Fayette Taylor, MIT '29.

Jim Dine, *Celebration 1981*, 1981, lithograph with silkscreen. Gift of Howard W. and Elizabeth Johnson.

Bruce Nauman, *Untitled*, 1971, lithograph. Gift of Howard W. and Elizabeth Johnson.

Friedel Dzubas, *Untitled (Museum of Fine Arts)*, 1981, silkscreen. Gift of Howard W. and Elizabeth Johnson.

James Charlton, *Vertical Cell Condenser*, 1989, metal, glass and anti-freeze. Gift of the Artist.

Ellen Banks, *Improvisation*, 1990, mixed media on canvas. Gift of the Artist, in tribute to Bernard T. Feld upon his retirement from MIT.

Jonathan Lasker, *Born Yesterday*, 1990, silkscreen with areas of hand-painting. Gift of Gift of the Albert and Vera List Family Collection.

Robert Mangold, *A Book of Silk Screen Prints*, 1973-76, printed 1977, seven silkscreens. Gift of the Albert and Vera List Family Collection.

Sol Lewitt, *A Square with Colors Superimposed within a Border with Colors Superimposed*, 1991, portfolio of six aquatints. Gift of the Albert and Vera List Family Collection.

Permanent Collection , continued

Tom Levine, *Sardines*, 1990, portfolio of 22 etchings. Gift of the Albert and Vera List Family Collection.

Ann Hamilton, *In the Time it Takes to Fry a Locust*, 1987, color photograph from a performance piece. Gift of the Albert and Vera List Family Collection.

Student Loan Art Collections

Nam June Paik, *Robespierre*, 1989, etching and lithograph. Purchased with funds from the Student Center Preview Program.

Todd McKie, *Two Bugs and a Snake*, 1988, monotype. Purchased with funds from the Student Center Preview Program.

Aaron Fink, *Coffee Cup*, 1986, etching. Purchased with funds from the Student Center Preview Program.

Rob Moore, *Winter Series II*, 1988, monotype. Purchased with funds from the Student Center Preview Program.

David T. Hanson, *Colstrip, Montana: Excavation, Deforestation and Waster Ponds, June 1984*, 1984, Ektacolor print. Purchased with funds from the Student Center Preview Program.

Sandy Walker, *Tree/Ghost*, 1987, woodblock on suzuki paper. Purchased with funds from the Student Center Preview Program.

Nancy Burson, *Mankind*, 1983-85, silver print. Purchased with funds from the Student Center Preview Program.

Barbara Norfleet, *White Pigeon and Broken Wine Glass*, 1986, Cibachrome print. Purchased with funds from the Student Center Preview Program.

Zeke Berman, *Untitled (Diptych)*, 1988, gelatin print. Purchased with funds from the Student Center Preview Program.

Michael Byron, *One of Three Individual Monotypes on John Koller Hand-Made Paper*, 1989, monotype. Purchased with funds from the Student Center Preview Program.

Al Taylor, *Untitled (Double Spiral)*, 1988, etching. Purchased with funds from the Student Center Preview Program.

Brodsky & Utkin, *Diomed II*, 1989/90, etching printed on German etching paper. Purchased with funds from the Student Center Preview Program.

Erik Bulatov, *Perestroika*, 1990, lithograph. Purchased with funds from the Student Center Preview Program.

Holly Morse, *I Missed 'Em*, 1990, watercolor on paper. Gift of the Albert and Vera List Collection.

Claudia Hart, *Defile*, 1990, reverse wood block on rice paper. Gift of the Albert and Vera List Collection.

Ida Applebroog, *Untitled*, 1989, screenprint on rice paper. Gift of the Albert and Vera List Collection.

Judith Murray, *Untitled*, n.d., silkscreen. Gift of the Albert and Vera List Collection.

Helen Frankenthaler, *Mary, Mary*, 1987, lithographic reproduction of a painting. Gift of the Albert and Vera List Collection.

Student Loan Art Collections, continued

David Morrison, *Mind Trap*, n.d., lithograph on black paper. Gift of the Albert and Vera List Collection.

Harry Nadler, *Untitled*, 1990, silkscreen. Gift of the Albert and Vera List Collection.

Steve Joy, *Untitled*, 1991, silkscreen. Gift of the Albert and Vera List Collection.

Steve Joy, *Untitled*, 1991, silkscreen. Gift of the Albert and Vera List Collection.

EXTENDED LOANS TO THE COLLECTION

Richard Artschwager, *3 Trees (Shark)*, 1981, mixed media. Lent by Agnes Gund.

(See also previous annual reports.)

LOANS FROM THE PERMANENT COLLECTION

Thomas Hart Benton, *Fluid Catalytic Crackers*, 1945, to the Nelson Atkins Museum of Art, Kansas City, MO, for the exhibition **Thomas Hart Benton: an American Original**, April - June 1989 and subsequent tour to the Detroit Institute of Art, The Whitney Museum of American Art, New York, and the Los Angeles County Museum of Art.

Betye Saar, *View of the World from Saturn*, 1988, to The New Museum of Contemporary Art, for the exhibition **The Decade Show**, May - August 1990. This exhibition was co-organized by The New Museum, the Museum of Contemporary Hispanic Art and The Studio Museum in Harlem, all of New York, NY.

Victor Burgin, *Danaïdes/Dames*, 1986, to Karl Bornstein Gallery, Santa Monica, for exhibition September - October 1990.

Per Kirkeby, *Untitled*, 1988, to the Museum of Fine Arts, Boston, for the exhibition **The Unique Print**, September - October, 1990.

James Rosenquist, *Sheer Line*, 1977, (extended loan to MIT Permanent Collection) to Central Hall of Artists, Tretyakov, Moscow, USSR for a James Rosenquist Retrospective exhibition, February - March 1991.

CONSERVATION OF THE PERMANENT COLLECTION

Restorative work was performed on Emile Antoine Bourdelle's *Tragic Mask of Beethoven* by Dædalus, Inc. of Cambridge.

Jean Lurçat's wool tapestry *La Mort et le Guerrier ou Hommage à Garcia Lorca* was cleaned.

Auguste Rodin's *Large Head of Iris* and Ros Newman's bust of *Sherman Fairchild* were resurfaced, polished and their pedestals repainted.

Restoration and repairs were made on Thomas Hart Benton's *Fluid Catalytic Crackers*, Jasper Johns' *Figure 7*, and Ludwig Sander's *Corinth VI* by the Center for Conservation and Technical Studies, Harvard University.

Harold E. (Doc) Edgerton and Kim Vandiver's large-scale color Schlieren photograph *A .22 Caliber Bullet Passing Through the Hot Air Above a Candle* was restored by Salozzo Airbrush Services of Boston, and re-framed by The Old Cambridge Company of Charlestown, in preparation for re-siting in the corridor of Building. 10.

Twenty-five works on paper were framed or re-framed by The Old Cambridge Company.

MIT Museum

MIT's international reputation gained an additional dimension in FY91 with the MIT Museum's enormously popular exhibition **Crazy After Calculus: Humor at MIT** and by the publication of a companion book highlighting MIT's history of high-tech hijinks, *The Journal of the Institute for Hacks, Tom Foolery and Pranks at MIT*. From *Newsweek* to National Public Radio, from the wire services to syndicated television, as hacks became a household word, so did the notion that MIT is less about self-importance than it is about ingenuity. "At Harvard, they always seem to be laughing at the rest of the world. The nice thing about MIT humor is that they're usually laughing at themselves," said Mark Starr of *Newsweek*.

In FY91 the Museum made other aspects of MIT history and culture accessible to the community at large. Works by renowned photographers Doc Edgerton and Berenice Abbott, musician and laser artist Paul Earls, and Media Lab holographers were showcased.

The Museum helped bring the regional display of the NAMES Project AIDS Memorial Quilt to MIT's Johnson Center in the fall, hosted a NAMES Project fundraiser, and also mounted an exhibition of international AIDS posters which reflected the diversity of issues and cultural attitudes about AIDS. To help mark World AIDS Day, December 1, the Museum co-sponsored an AIDS awareness poster contest, which resulted in the winning poster's distribution to all students and staff at the Institute and to the Cambridge schools. The contest was supported in part by the Council for the Arts at MIT.

FY91 also saw the opening of **MathSpace**. A hands-on gallery located adjacent to our **Math-in-3D** exhibition, **MathSpace** allows children and adults the opportunity to "play" geometry. MIT student-staff members assisted weekend visitors in activities to make mathematics fascinating and fun. Because of the popularity of **MathSpace**, the Museum has launched plans to enlarge and expand the area and activities provided to our visitors.

EXHIBITIONS AND PROGRAMS

Visual AIDS III September 21 - January 7

The premiere exhibition of 50 international posters, organized by James Miller of the University of Western Ontario from his collection of 700 AIDS posters, was timed to coincide with the regional display of the International AIDS Quilt at MIT. Posters were divided thematically: death, desire, defiance, and defense, and reflected a range of attitudes, political interests, and social agendas.

Lawrence B. Anderson '30: Artist, Educator, and Architect September 27 - December 28

This exhibition celebrated the former Dean of the MIT School of Architecture's distinguished career. Highlighted were his Beaux Arts student drawings, building plans and watercolors. The Council for the Arts at MIT funded the restoration of Anderson's 1930 Paris Prize drawings, and the Martin E. Zimmerman '59 Architectural Exhibition Fund made the exhibition possible.

Awon Orisa: The Gods / Africanisms in the Americas October 13 - January 18

Exploring the manifestations of Yoruba religious beliefs in the Americas was the theme of this exhibition curated by Dr. Reginald Jackson. A lively schedule of events complemented photographs and artifacts depicting the domains of the orishas and divinatory rituals, including performances by students from the Martin Luther King School in Cambridge, the Art of Black Dance, and a Kwanza celebration held by MIT students in the exhibit space. Several classes from the King School also visited the Museum to attend gallery lectures by Dr. Jackson.

Berenice Abbott November 8 - December 30

Cityscapes, portraits, and scientific prints by this quintessential American photographer in an exhibition which celebrated the opening of the Berenice Abbott Photography Laboratory at MIT's new Multi-Media Center. Widely regarded as America's greatest living photographer, Abbott has captured the nuances of twentieth-century America as few artists have. Abbott became fascinated with corroborating scientific laws through photographs illustrating such phenomena as gravity, motion, and magnetism. Her involvement with science and technology led Abbott to MIT in the 1950s where she worked with the Physical Science Study Committee to provide photographic illustrations for textbooks.

Memories of Eddie: Living with AIDS January 8 - February 24

Part of the Museum's series of exhibitions "AIDS: A Continuing Concern," these photographs by artist Loel

Poor documented the transformation of a North Shore man as he battled a series of AIDS-related diseases. Photographed over an eight-month period, Eddie requested these powerful and revealing portraits be taken so that he might "leave behind something that would dignify the suffering [he had] experienced."

The Art of Architecture: The Christian Science Church Center 1894-1990 January 14 - March 8

This exhibit featured the architectural plans and detailed scale model for the famous church.

American Color January 24 - March 15

Cibachrome photographs of American icons by popular photographer Rodger Kingston.

Robert Preusser February 7 - April 7

A retrospective exhibition of the paintings of Robert Preusser, Professor Emeritus of MIT's Department of Architecture.

Crazy After Calculus: Humor at MIT April 1 - September 20

Chronicling MIT's rich history of wit and wizardry, the exhibit features historic photographs, cartoons, and of course a collection of artifacts associated with some of the most renowned hacks perpetrated by MIT students. The exhibit was funded by the Peter de Florez '38 Fund for Humor at MIT.

Affiches Affisse Plakate! Swiss Poster Art 1906-1990 from the Ciba-Geigy Collection April 26-June 16

A catalogue and educational lectures accompanied the 90-poster exhibit, which mirrored European art movements and the development of printing technology, as shown in works by Max Bill, Armin Hofmann, Otto Baumberger, and other 20th century Swiss designers. A companion brochure with text by Anneliese Harding was supported by the Council for the Arts at MIT.

La Fee de Electricite April 15

Ten-section colored lithograph by Raoul Dufy depicting the history of electricity. The work is a gift of Freddy Homburger, and its restoration was funded by the Acquisitions Committee of the Council for the Arts at MIT.

Watercolors by Freddy Homburger April 26 - September 12

Twenty-five landscapes by the former honorary Swiss Consul. This Swiss-born physician, scientist, diplomat and artist studied under Raoul Dufy.

Boston Fisheries 1900-1920 May 2

Photographs documenting fishing from Boston's T Wharf area. On display at the Hart Nautical Galleries.

Winning Photographs from the Edgerton/Mili Photography Contest May 13 - September

Contest-winning photographs by MIT students on display at Strobe Alley.

Demarcating Lines: Urban Projects for Beirut June 1 - July 19

Design projects by young architects addressing the current urban environment in Beirut, Lebanon. Organized by members of the MIT Department of Architecture, this exhibition will be installed at the American University of Beirut later this summer. This exhibit was supported in part by a grant to the Department of Architecture from the Council for the Arts at MIT.

Harold Tovish: Tenant, 1964-65 June 25

Sculptural installation utilizing stroboscopic light by Center for Advanced Visual Studies Fellow Harold Tovish.

Special Exhibits and Programs

Several other exhibits were executed for various MIT departments and special events. Vannevar Bush and Edward Bowles were the subjects of panel exhibits for special programs. The Laboratory for Information and Decision Systems funded a major retrospective exhibition on the history of the "Servo" Lab. A three-panel exhibit commemorating MIT's 1916 move to Cambridge was completed for Alumni Weekend.

In March **Postcards from Ogunquit**, an exhibition of *pochades*, or quick sketches, by Charles H. Woodbury, Class of 1886, was organized and exhibited at the Guild of Boston Artists. Woodbury was a founding member of the Guild. The exhibition was then shown at the Christian Science Center before moving to the Museum for the summer. The restoration of these sixty oil paintings was a gift of Morton C. Bradley, Jr.

Traveling Exhibitions

Earth, Sea, and Sky, the major exhibition of works by Charles H. Woodbury, continued its three-year tour with venues at the Thomas Gilcrease Institute of American History and Art, the Telfair Academy of Arts and Sciences, the Museum of the Southwest, and the Bergstrom-Mahler Museum. **Seeing the Unseen: Photographs by Harold E. Edgerton** opened its nationwide tour in October at the Orlando Science Center, followed by venues at the Anniston Museum of Natural History and the Science Museum of Connecticut. It is scheduled for exhibition in an additional thirteen venues over the next three years. This exhibit was

supported by the Edgerton Foundation.

EDUCATION

In view of the Institute's increased commitment to K-12 education, the Museum closely examined its own contributions in this area. With the aid of a consultant funded by an Institute for Museum Services General Operating Support grant, the staff developed Museum resources to further visitors' enjoyment of experiences with math and science, using the Museum's exhibitions as a focus.

Throughout the winter and spring, Cambridge classes participating in the COSMOS program based at the Boston Museum of Science visited the MIT Museum for an exploration of the **Math in 3D** exhibit and our collection of fascinating math manipulatives. Another set of COSMOS programs included a visit to the MIT Strobe Lab where students discovered the value and excitement of Edgerton's stroboscopic photography. These programs were supported by the MIT Electrical Engineering Department.

MathSpace, our hands-on math room which opened in the fall, proved to be a very popular spot for Museum visitors of all ages to think and play. Renovation of additional space this coming year will enable the Museum to accommodate larger classes and groups of children.

In FY91, the Museum sought more community participation in its programs and exhibits, a good example of which was **Awon Orisa: The Gods / Africanisms in the Americas**. Local children visited the Museum as part of the curriculum developed around this exhibit. Children from the neighboring Martin Luther King School participated in an Orisha play which was performed as part of the exhibit's opening festivities. The curriculum and other educational materials and activities were supported by the MIT Community Service Fund, the Council for the Arts at MIT, and the Massachusetts Cultural Council.

COLLECTIONS

The Museum's Collections are the repository for scientific and technological instruments, audio-visual materials, and personal and professional memorabilia of MIT notables. Items from the Collections are frequently used as the basis for exhibitions, such as this year's **Crazy After Calculus**, **Lawrence B. Anderson '30: Artist, Educator, and Architect**, **Postcards from Ogunquit**, and **Doc Edgerton: Stopping Time**.

Consultant Kimberly Shiland undertook a survey of the Museum's Architectural Drawings Collection, more than 15,000 student project and thesis drawings dating from the 1860s to the 1960s, funded by a grant from the Graham Foundation for Advanced Visual Studies. As an outgrowth of her research, planning and fundraising for an extensive project to produce a computerized catalogue, monograph, and videodisc have begun.

An Institute of Museum Services Conservation Assessment Program grant was used to engage two consultants to survey the museum's collections and environmental conditions. Their reports are being used as a basis for raising further funds from IMS for conservation purposes and upgrading collections facilities.

A grant from the Acquisitions Committee of the Council for the Arts at MIT made possible the restoration of three important works including the portrait of William J. Walker by Henry Cheever Pratt. Walker was the first important benefactor of the Institute and this portrait purchased in 1867 was MIT's first work of art.

The first major project of the new curator of the Hart Nautical Collections was to organize and catalogue the William Baker collection. Baker was the longstanding curator of the Hart Collections who left behind a legacy of ship designs, a myriad of publications, and the reconstructed Mayflower II at Plimoth Plantation. This project is being supported by a generous gift from Ruth Baker.

FY91 was typically busy for the Collections staff as instruments such as an EE Lisp computer, a Harris parimeter from Brain and Cognitive Sciences, and a gravitational wave detector were added to the collections, reference questions from within and without MIT were researched, and photographs and videos were reproduced for clients ranging from *The Journal of Irreproducible Results* to the Art Gallery of Nova Scotia. Materials from the Collections were supplied to hundreds of patrons for such purposes as the Rad Lab's 50th

anniversary, the 75th anniversary of MIT's move to the Cambridge campus, and the 100th birthday of Vannevar Bush. James Ossi's Bubble Machine was loaned to the Boston Museum of Science for inclusion in its major gems exhibition.

Plans were made to collaborate with the Center for Educational Computing Initiatives to produce videodiscs of various segments of the collections using CECI's Muse software environment. The first to be implemented will explore Doc Edgerton's photographs, films, instruments, and diaries using a multimedia, interactive approach. The resulting videodisc and catalogue will be made available to the Institute via Athena visual workstations.

Paintings and furnishings from the Collections were provided for the President's house and office, as well as the Provost's and Chairman's offices.

OTHER HIGHLIGHTS

Administrative

- The Museum received its third Institute of Museum Services General Operating Support grant (\$74,438), which was used to fund an educational consultant, salaries for several staff members, and a variety of exhibition-related expenses.
- Director Warren Seamans received the Gordon Y. Billard award for "special service of outstanding merit performed for the Institute."
- Two new staff members, Kurt Hasselbalch, the Curator of the Hart Nautical Collections, and Paul DeFanti, Museum Shop Manager, joined us this fall.
- The Museum organized a panel of museum educators which explored continuing Harold "Doc" Edgerton's legacy to education. The panel members met with various associates of Doc and their report is under consideration by an Institute committee.
- In conjunction with the MIT Alumni/ae Association, the Museum organized a student photography contest to commemorate the work of Doc Edgerton and Gjon Mili. The winning photographs are on display at Strobe Alley through the summer, and will be featured in a calendar being produced by the Alumni/ae Association.

Facilities

As a service to the MIT community, the Museum makes available its facilities for departmental gatherings. In addition to seven exhibit openings, the Museum hosted seventy-four functions for MIT departments and other groups in FY91. These events brought almost 6,000 additional visitors to the Museum this past year.

Museum Shop

The MIT Museum Shops continued to serve the needs of the MIT community with their unique assortment of merchandise. Combined sales for the two retail stores and the mail-order business well exceeded the half-million dollar mark for the first time in FY91. About half of the sales were made to MIT alumni/ae, and efforts are being made to improve and expand our services to this very important constituency. The retail manager, Paul DeFanti, came to the Museum this past winter from Northeastern, where he managed that university's Student Center Services.

Publications

- In September the long-awaited *Journal of the Institute for Hacks, Pranks, and TomFoolery at MIT* was published, underwritten in part by the Peter de Florez '38 Fund for Humor at MIT.

SEMINARS AND LECTURES

- The director taught a Freshman Advisor Seminar on Institute history for the third year.
- The director presented his popular lecture, "Traditions at MIT," to incoming students, parents and alumni/ae groups.
- Graduate student Brian Leibowitz '82 presented his talk on hacks at MIT to several student and alumni/ae groups across the country.

The MIT Museum Staff

Associate Provost for Educational Programs and Policy

Office of the Dean for Undergraduate Education

Introduction

Six years ago, in July 1985, Professor Margaret MacVicar became Dean for Undergraduate Education. The creation of this new post formally reaffirmed MIT's recognition of the importance of the undergraduate curriculum. It began a period of curriculum review and reform that the Institute had not undergone for many years.

In addition to academic reform, the Dean sought to promote and to ease faculty engagement with academic and curricular issues. She wanted to foster a climate of innovation and experimentation. This required administrative and other resources to kindle new ideas, support them, and carry the resulting innovations through their fledgling periods.

Visions and programs need a staging area. The Office of the Dean for Undergraduate Education (ODUE), which began in 1986 as the Undergraduate Education Office (UEO) under the Dean, fills this need. UEO was built upon the existing Undergraduate Research Opportunities Program (UROP) office, which had solid, working ties with faculty and administrators throughout the Institute. It then incorporated a second academic program, the Writing Requirement, first implemented in 1983. Curriculum Support, the third element of the original UEO design, got underway in 1985 as a new activity intended to catalyze change.

Over the past five years Curriculum Support has become the predominant binding force within the Office of the Dean for Undergraduate Education. Curriculum Support activities have evolved from small-scale efforts to link mathematics and physics recitation sections to a much broader focus. This evolution has increased the level and diversity of ODUE work.

In the summer of 1990 ODUE modified its organization to accommodate the increase, and specifically to manage a growing number of activities involving evaluation of educational programs, support for MIT involvement with elementary and secondary schools, and resource development for undergraduate education. The result was two overlapping entities within ODUE: the Undergraduate Education Office (UEO), headed by Ms. Norma McGavern, and Educational Studies and Special Projects (ESSP), headed by Dr. Gregory A. Jackson.

The narrative below distinguishes between UEO and ESSP when this serves to clarify. In general, the distinction between the two organizational units is a matter of perspective and emphasis, rather than a clear division between two sets of activities. As a guide, the descriptions below headed **Core Curriculum Activities, Curriculum Activities Beyond the Core, Support to Faculty and Teaching, Undergraduate Research, and Writing Requirement** arise primarily from UEO, while those headed **Educational Studies, Development, and Elementary and Secondary Education** arise primarily from ESSP.

Affirmative Action

UEO and ESSP have few staff overall, with an authorized strength of six professionals, an office manager, and three support staff. Two positions were filled this year: program administrator of the Undergraduate Research Opportunities Program (UROP), and senior staff assistant to the UROP program administrator. There were nearly 100 applicants for program administrator, a professional position which was widely advertised. It was filled with an African-American man. The second, support position was filled by an Asian-American woman.

Students from minority groups underrepresented at MIT are further underrepresented in UROP. This has been true for some time. This year UROP staff organized discussions of this pattern with the Office of Minority Education, the Association of African American Administrators, and Undergraduate Academic Officers. ODUE will work with these organizations to address and to solve the problem. Information about UROP has been specifically addressed to minority groups, and UROP's new program administrator has made special efforts to carry forward the message of participation.

Institute Committee Membership

ODUE staff serve on several Institute committees, often representing the Dean but sometimes representing ODUE itself. This year Ms. Norma McGavern was a guest member of the Committee on the Undergraduate Program (CUP). She represented the Dean on the Committee on Academic Performance (CAP), and, with Dr. Leslie Perelman, served on the Committee on the Writing Requirement. Dr. Gregory Jackson represented the Dean on the Committee on Undergraduate Admissions and Financial Aid (CUAFA) and the Committee on K-12 Education. Ms. Margaret Enders served on the Committee the Science Requirements, the Committee on Curricula (COC) and the ROTC Committee. Dr. Perelman was a member of the IAP Policy Committee.

Core Curriculum Activities

ODUE's core-curriculum activities encourage collaboration across disciplines and within disciplines, help fulfill MIT's responsibility to educate the entire spectrum of students it admits, and assist efforts to improve teaching and learning.

Science core. An early UEO goal was to promote interaction and cooperation among departments involved in teaching core subjects. Efforts to link math and physics recitation sections have evolved into meetings among members of Core teaching staffs. These continued to be well attended and popular this year, and now include instructors from the chemistry core subjects 5.11 and 3.091. ODUE invited Core recitation instructors to a series of informal luncheon meetings to share opinions and concerns about their classes, their students, their expectations as instructors, and other educational issues. Besides sharing information among themselves, instructors and departmental representatives provided valuable feedback on curricular and teaching issues to the Admissions Office, the CAP, and the Undergraduate Academic Support Office, which were frequently represented at meetings. Lecturers in all science core subjects also met on a regular basis each term. These meetings took on a particular sense of urgency, given the impact of the new grading scheme (where D is no longer passing).

Undergraduate Academic Support Office (UASO). This year ODUE initiated a series of meetings with UASO to discuss and work jointly on activities which touch both offices. These meetings helped promote smooth interaction between individuals in the two offices, and increased the consistency of policies in areas ranging from academic orientation to grading policy to diagnostic and student-warning mechanisms.

New grading system. The faculty voted in May 1989 that Pass requires performance at the A, B, or C level, effective in fall 1990. The faculty also lowered the unit maximum for freshmen. Under the old Pass/Fail criterion (Pass equals D or better) students appeared to overload and to tackle upper-level subjects without proper foundation. ODUE encouraged discussion about the new grading standard among faculty, especially faculty teaching freshman subjects and HASS-D courses, and worked with UASO to help students adapt to the change in Pass/Fail. ODUE and UASO jointly reappraised old performance-evaluation practices, and worked with departments to adapt these practices to the new grading system, to identify students in academic difficulty, and to reach them with academic support as quickly as possible.

Math diagnostic. Freshmen enter MIT with very different preparation for Core science subjects. This caused much concern in discussions of the grading change, and in earlier discussions about admissions requirements. ODUE, working closely with several academic departments and UASO, proposed and is currently undertaking a freshman math diagnostic. The diagnostic's objective is to encourage students to review areas where they are poorly prepared, and to build confidence for those who feel-as most students probably will-that their math skills are well above the demands of the test. Work on the diagnostic brought together ODUE staff, Professor Anthony French of the Department of Physics, faculty from the Department of Mathematics, and a number of others.

A self-administered test, with solutions and references to resource material, went to all incoming students in June 1991. ODUE is providing review modules which will be sent out during the summer, upon request, to students who feel their math skills are rusty. A similar but different diagnostic will be taken by all students during R/O. This test should help students choose their first physics and math subjects, and encourage underprepared students to seek help early in the term. Plans are afoot for review sessions during the first weeks of the term for students who want help. Plans are also afoot to analyze data from the diagnostic, and to raise issues brought forth by diagnostic results with academic departments.

Curriculum Activities Beyond the Core

Beyond its interest in the core curriculum, ODU also tries to improve communication among engineering, science, and less technical departments at MIT, and to nurture innovative efforts involving many disciplines and teaching styles.

Context. The CUP based its Context initiative on the premise that students should learn that technology, social structures, and intellectual constructs influence each other and evolve together. By encouraging already existing contextual subject and special seminars, CUP hoped students would consider the full range of influences on their individual disciplinary areas. The Context initiative encouraged "natural" and existing contextual courses or activities, and initiated other efforts as appropriate.

The seminar series "MIT, in Reality" was one of the latter Context activities. It featured well-known faculty speaking on a variety of topics such as jobs and the economy and toxic waste disposal. Attendance at the "MIT, in Reality" series was disappointingly small, as it had been for last year's Context courses. Another series will not be attempted next year.

Context projects associated with other events were somewhat more successful, such as the context initiative's support of the 1990 R/O Week design project, a bibliographic project on ethics in engineering, IAP activities such as the faculty workshop on "The Art of Engineering," a field trip to the Lowell Industrial Park, and, as part of the "Teaching at MIT" series, a seminar on "Integrating Context Into Subjects." An advisory group composed of faculty and staff interested in furthering the Context initiative will help proselytize and stimulate Context ideas. It has already met several times.

Libraries. Several years ago ODU began facilitating contact between reference librarians and faculty teaching humanities (HASS-D) subjects to improve students' awareness and use of library materials. This year ODU sponsored a pilot library liaison program in Professor Jeremy Wolfe's popular subject 9.00, "Introduction to Psychology." Librarians attended meetings of each section and helped students locate, select and evaluate materials for each of the three required research papers. Professor Wolfe and his teaching assistants reported dramatic improvement in the quality of the resulting papers. The library liaison project will continue next year in 9.00, and expand to other subjects in the humanities and social sciences.

Undergraduate academic officers. ODU held regular meetings throughout the year for all departmental undergraduate academic officers, as it has before. These meetings provided undergraduate officers a chance to interact with faculty committee chairs about ongoing educational reviews. The meetings continue to provide one of the few opportunities for faculty education officers to share concerns about general issues relating to the curriculum, the advising system, and academic programs and policies. It also helps undergraduate officers simply meet on an informal, collegial basis, thereby promoting cross-departmental knowledge and interaction.

Curriculum development. ODU encouraged and assisted the Literature faculty in applying to participate in a Curriculum Review project administered by the Modern Language Association under a grant from the Fund for the Improvement of Post Secondary Education to reconsider curricula and teaching in the light of challenges presented by the diversification of students and faculty, the retirement and replacement of faculty members, and the reconfiguration of thought in the humanities.

Support to Faculty and Teaching

ODU helps faculty members fulfill their commitment to the undergraduate curriculum and improve the effectiveness of their teaching. New faculty members receive special attention. ODU's support for faculty members has historical roots in UROP support for faculty research and, through research mentorship, teaching.

Classroom teaching. Working with the School of Engineering Faculty Instructional Resources Program (FIRP), ODU has helped provide faculty members feedback on the effectiveness of their teaching, using class videotaping as a basis for the feedback. ODU and FIRP offered a series of four seminars during the fall term, aimed particularly at helping junior faculty improve their teaching technique. The topics of these seminars included "Planning and Teaching an Engineering Subject," "How to Lecture," and a Context session we

mention below. During this year, the Dean of Science made it possible to extend class videotaping services to faculty members in departments involved with the Science core.

During IAP, ODUE organized a series of five seminars on teaching-related topics. "Teaching at MIT" was offered in concert with the Context Initiatives project, the Writing Program, the Experimental Studies Group, the Artificial Intelligence Laboratory, the Departments of Physics, and the Department of Electrical Engineering and Computer Science. On balance, the series was well-received. In some cases, it was exceedingly well-attended. A seminar entitled "Learning from Your Colleague's Teaching" attracted over 30 MIT instructors.

New faculty. About 50 individuals join the MIT faculty each year. Some of these come from faculty positions elsewhere; some come fresh from doctoral or postdoctoral studies; and others come from industry, government, or other organizations. Most new faculty require some orientation to the challenges and opportunities of faculty life. Much of this is provided by their departments. Because many undergraduate-education policies and procedures at MIT are extradepartmental, for the past three years ODUE staff members have met individually with all new members of the faculty to talk about their initial impressions of MIT. These visits have provided insight into the elements that enable a first-year faculty member to succeed, and the kind and amount of teaching support he or she needs. ODUE plans to follow up on issues these interviews uncovered, such as the importance of mentorship, in the next year.

Tech Coop. Liaison to the Coop, initially begun after faculty complaints about classroom book problems, has continued with a meeting to explore Coop participation in the MIT computer network via E-Mail. In March, ODUE and the Coop organized a meeting of academic administrators in various departments. This attention has led to continued improvement of relations between MIT and the Coop, with a dramatic decrease in the number of faculty complaints, and the Coop reporting satisfactory numbers of on-time book orders for most MIT departments.

Undergraduate Research Opportunities Program (UROP)

Interest and participation in UROP have continued to be high. But conditions have changed a great deal in UROP's twenty-one years. ODUE's aim is to keep the program viable and fresh, and to use UROP's strongest qualities to promote good teaching and sensitivity to research issues.

Other universities continue to use MIT's program as a model for their own programs. Saint Mary's University in Halifax, Nova Scotia invited MIT's assistance this spring to learn how an innovation like UROP could influence their curriculum.

Participation and economics. The most evident trend this year in UROP participation was economic: there was unusually heavy demand for UROP-funded stipends during the term, and funding requests for the summer of 1991 approached an unprecedented \$700,000. This probably reflects the depressed national and local economies, which have eliminated many traditional ways for undergraduates to earn money. It will be exacerbated as the academic-year budget for students rises to \$24,250 and self-help (the amount students are expected to borrow or earn) rising to \$6,100 from \$5,700. Moreover, an increase in the minimum student-employment wage rate may spur an increase in the UROP stipend hourly rate for the fall of 1991 (a rate held at \$6.25 this year). This will increase the tension between demand for UROP funding and available funds.

UROP waived overhead on about \$3.6 million in sponsored research funds paid to UROP students in 1991, an increase from \$3.3 million in 1990 and \$2.9 million in 1989. The willingness of faculty to support research by undergraduates is evident. Nevertheless, there are ample indications that sponsored-research UROPs are becoming more difficult to fund, with federal government cuts and shifts research monies.

Participation in research involved well over half the undergraduates. About 40% of all UROPs were undertaken for credit during the fall and spring terms this year. This proportion has declined less than might have been expected (it was 43% in the 1984-1985 academic year) considering the increased demands for UROP financial support.

Ethics. UROP students periodically become interested in ethical issues growing out of their UROP work. Yet they seem to have no basis for considering these issues or acting on ethical principles. ODUE has initiated

discussions with various faculty members in an effort to develop ways of educating undergraduates about ethical issues in research. UROP is evaluating ideas such as encouraging faculty through the Institute to integrate ethics discussion into laboratory courses or other research-oriented syllabi, developing a student research guide, holding credit seminars during IAP on research issues, and the like.

The Writing Requirement

This year marked the first period of time when the entire undergraduate student body was subject to the Writing Requirement, every class present when the Requirement was initiated having now graduated. This has had the salubrious effect of erasing the collective student memory of an MIT *without* the demand for good writing. Most students now respond positively to the spirit of the Requirement, recognizing the importance of writing to their careers. Much of the success of the Requirement can be attributed to the efforts of departmental writing coordinators and the staff of the writing cooperatives in the Writing Program, especially Drs. Edward Barrett and Andrew Hawley.

The Committee on the Writing Requirement. This faculty and staff committee is working with departmental coordinators on ways to improve further writing instruction. It met with coordinators in October to discuss different strategies. The Committee is now reviewing representative Phase Two papers from all Institute departments to insure that departmental practices are roughly equivalent.

Progress for the Class of 1991. The Class of 1991 completed the Writing Requirement earlier than the preceding class, thus continuing a positive trend. By Registration Day of their final term at the Institute 89% of '91 class members had completed Phase Two in 1991 compared with 87% for '90, 70% for '89, 68% for '88, and 54% for '87. (Only five members of the Class of 1991 failed to graduate solely because they had not completed the Writing Requirement.) There was an increase in the number of students who fulfilled Phase Two through a writing subject, although the total percentage (11%) is still small. By far the largest proportion (47%) completed Phase Two through writing cooperative subjects.

Phase One. The Freshman Essay Evaluation (FEE) is offered to members of the incoming class once during R/O week and once during the fall term. Students are asked to write two essays for the evaluation. This year one of the essays was related to the freshman book and orientation events on design. The number of students taking the FEE increased from 729 in fall 1989 to 870 in fall 1990. During IAP, Writing Requirement Coordinator Dr. Leslie Perelman and Dr. Steven Strang of the Writing Program again offered a three-day Phase One writing workshop. This workshop yielded 14 essays that satisfied Phase One of the Requirement.

Educational Studies

Educational studies have a long and honorable history at MIT, extending back to the Lewis Commission of the late 1940s. They include the Student Adaptation Study and its followups, methodologically innovative evaluations of experimental freshman programs in the early 1970s, various studies and analyses undertaken by MIT Commission, the work of the Analytic Studies Group, and numerous other projects.

In the recent past educational studies have included three kinds of activity: studies to support discussion in standing and *ad hoc* Institute committees, studies of individual subjects (both experimental and "normal"), and ongoing studies that involve repeating a particular inquiry periodically or following a cohort of students. Many of these studies require collaboration among diverse Institute offices. During this year these different activities have matured and grown, as the examples below illustrate. More importantly, ODUE and its collaborators have sought to formalize the periodicity and collaborative structure of especially important educational studies, and to develop a peer-support organization and standard operating procedures to promote and expedite new educational studies.

Educational studies rarely proceed independent of other policy and support activities in undergraduate education. Therefore, several of the educational-studies activities below also appear elsewhere (and from a different perspective) in other sections of this report.

Educational Studies Working Group. ODUE has been taking steps to streamline and focus educational research studies across various MIT departments that undertake them. The primary vehicle for this has been an Institute-wide, relatively informal Educational Studies Working Group (ESWG) convened by ODUE. This

group includes members from ODUE, from the Office of the Dean for Student Affairs, from the Admissions Office, from the Planning Office, and from the Registrar.

Initially ESWG devoted much of its attention to several pressing procedural issues, such as access to "official" student data and related topics. With many of those issues resolved, the group has moved this year to greater substantive interaction. The group's monthly meetings have focused on specific educational research studies carried out by its members. These discussions have highlighted opportunities for collaboration and comparison across offices. They have highlighted research-design problems that require more prominence among researchers, and led to a draft *Guide for Educational Research Studies at MIT* (about which more below).

The ESWG was designed to promote peer interaction within the educational-research community at MIT, and to highlight themes running throughout educational research studies. It has gone beyond these goals to promote collaboration among its members, and to become a cross-cutting organization itself capable of designing and carrying out comprehensive studies of MIT education.

Class of 1991 interviews. In 1987-88 a random sample of 50 freshmen agreed to be interviewed periodically during their tenure at MIT. The interviewers were staff members from ODUE, ODSA, and several Departments with large undergraduate enrollments. The sample members represented the full diversity of MIT undergraduates, both in their entry characteristics and in their subsequent choices and experiences.

Staff in ODUE transcribed each interview. The collected interviews have provided a qualitative foundation for various inquiries about the undergraduate experience. Formal coding of the first two years' interviews has permitted more detailed analysis. In some cases the interviews have led to specific reports, such as a 1989 exploration of the relationship between test scores and freshman academic experiences for the Committee on Undergraduate Admissions and Financial Aid.

The final set of interviews with the Class of 1991 sample took place in the spring of 1991. The interviews have been transcribed. Over the next several months the final interviews will be integrated with the earlier ones, high-level coding of the full dataset will proceed, and the dataset (which does not contain student identities) will become available for interested and qualified researchers to use.

A comprehensive successor to the Class of 1991 Interviews, the Cohort Study, will get underway in 1992 or 1993. In addition to periodic interviews, the Cohort Study will retain (with full consent, of course) a full documentary account of students' progress to, through, and beyond MIT.

Senior letters. Each year the Associate Provost for Educational Programs and Policy writes to graduating seniors soliciting reflections on their MIT education. Perhaps five percent of the class responds each year with various compliments and complaints. ODUE collects, collates, and classifies the responses. The resulting document -letters and summary -circulates widely within the MIT administration.

In the past the senior-letter solicitation has been open-ended, with suggested topics drawn rather haphazardly from the year's concerns. This year planning for the senior letter and for the final year of the Class of 1991 Interviews proceeded in parallel. As a result, the senior letter was somewhat more structured than it has been in the past.

The picture of MIT contained in the senior letters is biased in unknown ways, since response patterns are not monitored. This makes senior letters a questionable base for policy analysis. Nevertheless, they are provocative, both in content and language, and help refresh educational discussion at Academic Council and elsewhere.

Guide for Educational Research Studies. Some individuals who study MIT education are well trained and well integrated into relevant administrative structures. Others know little about education research or about accepted procedures for it at MIT. Since the demise of the Education Research Center and the Division for Study and Research in Education there has been no clear source of help with educational research studies.

The Educational Studies Working Group discussed this problem early in the fall of 1990, and agreed that a brief methodological document might help integrate and improve educational research studies at MIT. The resulting *Guide for Educational Research Studies at MIT* currently exists in draft form, and should be ready for distribution early in the fall of 1991. The *Guide* concentrates on research design and on privacy issues, summarizing general principles with examples and citations to more complete sources.

The intended audience for the *Guide* includes staff in offices that conduct educational research studies, departmental staff, students taking subjects with assignments that involve educational research students, faculty members chairing key committees, and faculty members with known or likely interests in educational research studies.

Undergraduate Educational Commons. In 1988-89, the Committee on the Undergraduate Program developed the Commons Initiative. The Commons Initiative sought to recognize and encourage participation by regular faculty in undergraduate academic activities that are outside of traditional departmental purviews. For the past two years, the ODUE has provided administrative support for the Commons Initiative. It has collected data on participation from the various undergraduate activities. It has reported on the Commons to the CUP, and prepared an annual Commons report for School deans and Department heads.

In its discussions on the Commons, the CUP emphasized that the list of specific activities classified as Commons can never include all faculty contributions to the undergraduate program. The Commons report needs to be redefined each year so that it will represent the breath of faculty participation in undergraduate education. Beginning with thereport for academic year 1990-91, for example, the report will recognize the contributions of faculty members to undergraduate participation in the Arts.

The Commons report sent to school deans and department heads in January highlighted the diversity of ways with which Institute schools and departments involve themselves in undergraduate education. The Report also underscored the continuing unmet need for greater faculty participation in such areas as freshman advising, admission folder reading, and undergraduate seminars.

Student workload. During the past few years, both the Committee on Curricula and the Committee on the Undergraduate Program have expressed concern that the number of credit units listed in the *MIT Bulletin* does not always reflect the average number of hours MIT students actually spend on those subjects.

During 1989-90, ODUE used data from the *Course Evaluation Guide's* student evaluation forms to appraise differences between the average amount of time reported by students and official credit hours. However, because of the manner in which it is collected and its inherent nature, the *CEG* data always misrepresent the actual number of hours students spend on a particular subjects. Students report the amount of time they spend on a subject only once, at the end of term. Such reporting may distort data from subjects whose time demands fluctuate. Furthermore, the *CEG* data cannot reveal the effect of time demands from one subject on the amount of time a students devotes to other subjects.

As a consequence, ODUE, in consultation with the Committee on Curricula, authorized a pilot study of student workload. The goal of the project is to know how MIT students allocate time to coursework, and what influences the distribution of time across different subjects.

During the Fall 1990 term, ODUE had 37 randomly selected sophomore and junior students fill out a daily diary indicating all the time spent on MIT subjects. Analysis of these data continues. Preliminary analysis have been discussed with the Committee on Curricula in September, with Undergraduate Academic Officers in February, and with the CUP in March. The pilot study was extremely successful both in demonstrating that this kind of study is practicable at the Institute and in providing several hypotheses that will be explored further in a larger study that will be conducted in 1991-92.

Development

For structural reasons undergraduate-education needs have sometimes been underrepresented in solicitations from the Campaign for the Future, the Alumni Association, and the Development Office to outside donors. To remedy this a substantial fraction of Dr. Gregory Jackson's time goes to working with development officers

generally to increase their awareness of undergraduate-education needs, and specifically to elaborate ideas and proposals for individual or organizational donors. The list below illustrates this area of ODU work.

Priorities document. Until this year development officers worked on undergraduate education *ad hoc*, with no general guidance as to the range of needs or their relative priority. In the spring of 1991 ODU published a *Development Priorities for Undergraduate Education*, with brief descriptions of almost fifteen areas in need of resource development. This document, which will be updated periodically, now serves as a foundation for increased interaction between ODU and the several development offices.

Specific projects. Several development proposals and collaborations have emerged from ODU this year, with varying results. An alumnus with interests in teaching quality received proposals to create a teaching-support center and to endow a set of teaching-support grants for new faculty. Another alumnus received proposals to provide major endowment for UROP or to help build and equip the new Science Teaching Center. A major foundation solicited MIT's interest in a program to promote science-teaching careers among minority students. MIT collaborated with the Commonwealth of Massachusetts Department of Education on a major federal proposal to reform science education in the state. Several corporations considered proposals for post-Athena educational computing.

Elementary and Secondary Education

The ODU interest in elementary and secondary education stems partly from the curricular demands of MIT undergraduates who become interested in school teaching, and partly from the Dean's advocacy role in this area at MIT and nationally. The resulting activities fall into three categories: program development for MIT undergraduates, collaborative internal efforts to increase MIT's contributions to elementary and secondary education, and external activities on MIT's behalf.

MIT undergraduates. Each year a few MIT students become school teachers after they graduate (the number seems to be rising steadily from about ten annually to perhaps twice that), sometimes for a few years and sometimes for a career. These students must be certified if they wish to teach in public schools. Becoming certified requires either some coursework and practice teaching between graduation and first job, or somehow reconciling certification requirements with undergraduate requirements.

For several years MIT undergraduates have been able to enroll in certification-related subjects at Wellesley College, and to do practice teaching under the supervision of Wellesley faculty members. Recently ODU arranged for MIT undergraduates to have similar access to Harvard University's Undergraduate Teacher Education Program. Some MIT Courses have requirements that conflict substantially with these two pathways to certification. ODU has worked with individual students, with MIT departments, and with Wellesley and Harvard to minimize these conflicts. In addition, Wellesley has agreed that new MIT graduates may take advantage of its fifth-year certification program, which provides coursework and practice teaching at a cost much lower than MIT's full-time tuition.

In 1993 certification requirements in Massachusetts will change dramatically. Last year ODU staff held meetings with representatives of the Commonwealth and the Cambridge Public Schools to explore possibilities for a new, collaborative, school-based certification program under the new regulations. These discussions continue, and will expand to include two or three further partners.

ODU also guides and advises students interested in school teaching, in collaboration with the Undergraduate Academic Support Office and faculty members from MIT and Wellesley. In the fall of 1990 ODU published a brochure entitled *So You Want to Teach School*, which went to all freshmen and sophomores and to all academic advisors.

MIT contributions. Depending on definitions, there are between 20 and 60 "outreach" programs whereby MIT contributes human or technical resources to elementary and secondary education or collaborates with others to do so. ODU staff have been involved in several of these. During 1989-90 ODU helped organize several meetings spanning the diverse outreach programs, to help identify common themes and goals across the program.

In the fall of 1990 the Dean of Engineering appointed a faculty and staff committee to recommend broad themes and mechanisms for MIT's involvement in elementary and secondary education. Dr. Jackson of ODU

was on this committee, representing both ODUE's interests and his own prior experience in the domain. The committee met frequently throughout the year, submitting a preliminary report to the Dean in January and, following a succession of Deans, submitting a final report to the President and Provost in June.

Representation. ODUE represented MIT on several outside panels and committees concerned with elementary and secondary science education. Among these four were especially important: the AAAS National Council on Science and Technology Education (part of Project 2061), the Cambridge Science Advisory Committee (part of the Cambridge Partnership for Public Education), various subcommittees connected with the reform of teacher certification in the Commonwealth of Massachusetts (part of the so-called JTTP process), and the Steering Committee for the proposed Massachusetts program Systemic Change for Learning and Teaching Mathematics, Science, and Technology.

Notes on Space and Staff

By the beginning of the fall 1990 term, the renovation and enlargement of ODUE's space in Building 20 was completed. All staff were gratified, relieved, and thankful. The renovation brought a dramatic improvement in ODUE's working and service environment, even though the all the furnishings were recycled. Operations have been noticeably smoother and the atmosphere has become more welcoming to student, faculty, and staff visitors.

Mr. Claude Poux joined the staff as UROP program administrator in late July 1990. At the same time Ms. Jane Sherwin left the position of assistant dean for undergraduate education. Ms. Sherwin stayed with the office on a temporary basis until she gave birth to a baby in February 1991. Ms. Robin Pachtman was replaced as senior staff assistant in November by Ms. Sarah Tom, who is working primarily in support of UROP activities.

The members of the ODUE staff, in alphabetical order, are:

Ms. Margaret Enders, Assistant Dean
Ms. Maureen Horgan, Program Administrator
Dr. Gregory Jackson, Director of Educational Studies and Special Projects
Ms. Stacia Conklin Kraft, Senior Staff Assistant
Ms. Norma McGavern, Director of the Undergraduate Education Office
Dr. Leslie Perelman, Assistant Dean
Mr. Claude Poux, Program Administrator
Dr. Cynthia Rose, Office Manager
Ms. Sarah Tom, Senior Staff Assistant

Professor Emeritus Benson Snyder and Ms. Cheryl Butters continue their association with ODUE.

In addition, a diverse and enthusiastic corps of temporary and student workers carries out much of ODUE's day-to-day business. Deserving special mention is our long-term temporary support staff assistant and general factotum of the reception desk, Ms. Lynn Harris. Thanks are due to Mr. Eric Lormand, philosophy graduate student and our computer specialist. Also of great help to us this year were student workers Gregory Black '91, Tammy Cagann '94, Judy Jeanmonod '93, Pamela Monaghan '92, Monique Morin '92, Jalal Khan '94, and Kwasi Yirenkyi '93.

The year ended on a high note, so to speak, with a "Building 20 Concert," organized primarily by Ms. Horgan. This concert starred artists in our midst and among our Building 20 neighbors.

NORMA G. MCGAVERN, Director of UEO
GREGORY A. JACKSON, Director of ESSP

THE COMMITTEE ON THE UNDERGRADUATE PROGRAM (CUP)

The Committee on the Undergraduate Program (CUP) saw several ongoing initiatives through to completion this year. CUP and the Committee on the Science Requirement (CSR) presented a motion to the Faculty to implement a core Institute Requirement in Biology, beginning in the fall of 1993. Led by Professor Thomas Greytak, with the cooperation and initiative of the Department of Biology, the CSR (established in the 1989 motion recommending the Biology Requirement) examined the implementation question and brought its proposal to CUP's 1991 January Work Session. Throughout the spring, CUP and CSR worked together to craft the motion passed at the May Faculty Meeting which included the following provisions:

- The Biology Requirement will be satisfied by a single subject based on modern molecular biology, labeled 7.01n. This subject will be offered in several versions (7.011, 7.012, etc.), with each version having a similar core but emphasizing a different aspect or application of biology for students with differing backgrounds and interests.
- Also effective in 1993, the name of the Science Distribution will be changed to Restricted Electives in Science and Technology. To make room for the requirement in the curriculum, the number of subjects required in Restricted Electives in Science and Technology will be reduced from three to two; both of these may be specified by departmental programs, but no more than one may lie inside the department.
- An ad hoc committee appointed by the President will be formed to review the scope and balance of the General Institute Requirements as well as the Institute calendar and its implications for the academic program. The committee will report its initial findings to the Faculty during the 1991-1992 academic year.

The CUP also concluded its work on grading changes voted by the Faculty in 1989. The subcommittee on pass/fail assembled the final motion to implement the grading changes for juniors and seniors. The changes voted by the Faculty in November revised the *Rules and Regulations of the Faculty* to implement the P/D/F grading system for juniors and seniors in pass/fail subjects, effective in the Fall of 1992. CUP also reviewed freshman performance during Fall 1990, the first term in which freshman subjects were graded under Pass = C.

The Committee monitored several experimental projects, including: revisions to the freshman evaluation process, procedures dealing with transfer students, a pilot study of how students allocate their study time, a new early warning system for freshmen in science core courses, and a math diagnostic test for entering freshmen.

CUP requested reports from several committees and individuals throughout the year:

- President Charles M. Vest visited CUP to address issues affecting undergraduate education, including: the impact of student life issues on the undergraduate program, the necessity of a robust education that enables students to learn and evolve with rapid changes in national and international contexts, and the need to bridge the cultural boundaries between students and faculty.
- The Integrated Studies Program (ISP) review committee, chaired by Professor Anthony French, submitted its report recommending that ISP become a permanent component of the undergraduate program. CUP endorsed the report which included several other recommendations regarding ISP.
- The IAP Policy Committee informed CUP of its efforts to bolster faculty participation in teaching IAP courses, increase the number of credit-bearing activities, and facilitate the transfer of responsibility for organizing IAP offerings to academic departments.
- Leaders of the Undergraduate Association and the Student Committee on Educational Policy presented issues of particular importance to undergraduates, such as calendar and IAP concerns, HASS-D finals, the Writing Requirement, and diversity issues.

- Professor Sheila Widnall, Chair of the Committee on Discipline, visited CUP to address issues of academic honesty. The discussion revealed concerns about the risks students assume when they cheat. Several recommendations were made about ways to handle cheating at MIT.
- The Committee discussed issues affecting engineering education, including increased emphasis on teaching techniques, mentoring of engineering students and faculty, accreditation issues, and various proposals for five-year degree programs.
- Associate Provost for the Arts Ellen T. Harris reported on the various academic and community initiatives sponsored by her office.
- CUP made its annual examination of the Educational Commons, noting that the continuing study of participation in commons activities has been helpful in gaining recognition for faculty participants. The report has also proven useful to departments when formulating five-year plans.
- CUP also reviewed the reports of the Committee on Academic Computation, the MIT Committee on Sexual Harassment, and the MIT Committee on ROTC.

CUP bid farewell to departing members Professors Anthony French, Travis Merritt, William Siebert, J. Kim Vandiver, and David Wormley, Ms. Norma McGavern, and Messrs. Riad Bsaibes and William Buckner (undergraduate student members). Special thanks were extended to Professor Vandiver for serving as Deputy Chair of the Committee this year.

SARAH T. CAMPBELL
Secretary to CUP

COMMITTEE ON ACADEMIC COMPUTATION FOR THE 1990'S AND BEYOND

Provost John Deutch appointed this Committee in the spring of 1989 by to recommend different academic-computing paths that MIT might follow over the next decade. The Committee's Chair was Professor Margaret L.A. MacVicar, Dean for Undergraduate Education. Its members included faculty members from each School plus individuals representing different academic-computing organizations. Although the immediate impetus for the Committee was the upcoming end of Project Athena's major outside grants, the Committee's charge was to review academic computing generally.

The Committee circulated a discussion paper, *Computation and Educational Community*, in the spring of 1990. It submitted a final report, *Computing for Education at MIT*, in June of 1990. First, the Committee recommended that a two-pronged array of Basic Educational Services and Tools and of Educational Development Projects be integrated into MIT's academic structure. Second, it recommended a distinct research-and-development model for projects emphasizing cutting-edge technological development. Third, it recommended numerous organizational and financial mechanisms for implementing the first two recommendations, especially a merger between Information Systems and the operational side of Project Athena, and the identification of a research unit to house the advanced-development side of Project Athena. During the past academic year the Committee's deliberations have given way to diverse implementation activities.

During the summer of 1990 a small group of Committee members and academic-computing administrators met, at Academic Council behest, to reconcile Committee recommendations and highly constrained academic-computing budgets, and to begin orderly planning for the integration of Project Athena into other administrative units. The summer group identified a small subset of Committee recommendations that could be implemented under existing budget constraints, recommended cuts in existing Project Athena activities, and identified some additional funding sources for academic-computing operations. The summer group's proposals

were consistent philosophically with the Committee's recommendations, but fell far short of the recommended pacing and objectives.

With the appointment of a new Provost in the fall of 1990, implementation of the summer group's recommendations got underway, under the direction of a steering group composed of Information Systems and Project Athena managers and directors. At the same time Professor S. Lerman agreed to head a new Center for Educational Computing Initiatives, whose mission is to manage and raise funds for cutting-edge educational-computing development efforts.

With these two organizational changes in place the Committee's reports were distributed to the full Faculty and discussed at the April meeting. In addition, the Committee's recommendations and MIT's implementation of them have been the topic of a well-attended session at the Educom conference in October 1990 and an article in *Windows on Athena*. They will also be the basis of an article scheduled for *Change* magazine this fall.

In the Committee's view MIT has progressed substantially toward two of the Committee's broad recommendations (reorganization and a research-and-development group). Budget constraints and the abrupt end of outside funding have largely halted progress toward the other recommendation (two-pronged academic programs), thereby leveling and even reducing the penetration of academic computing into MIT education.

GREGORY JACKSON
Director of ESSP

RETROSPECTIVE ON THE LAST DECADE AT MIT from the perspective of a recent Emeritus

The education of undergraduates is but one of MIT's several missions, competing as it must for time and resources with graduate education, research, consulting, and funding for the entire enterprise. Ten years ago the flood tide supporting higher education began to ebb. MIT's course began to change. The consequences for undergraduate education at MIT were subtle at first, a shift toward simpler formulations of difficult educational issues, less informed by the faculty's and students' past or present experience. While many spoke about undergraduate education, deploring or extolling its pressure and pace or the changes in admissions, there was little sustained in-depth attention paid to the multiple difficulties that were increasingly apparent.

Navigating an educational institution on a falling tide, in shallower waters, requires attention to one's proximate position and extensive local knowledge. Most crucial is the ability to learn from error and alter course based on appreciation of the actual situation. A sense of possible alternatives rather than ideology makes for a more successful passage.

This was the context six years ago when Professor Margaret MacVicar became MIT's first Dean for Undergraduate Education. She had developed UROP in 1969, one of only a few educational innovations that has had a successful half life beyond three years. Its continued robustness derived from her conception of the program, which included from the outset rapid feedback about what was occurring so that reliable responses to crises or changed circumstances could be formulated. By this process, faculty, students, and administrators began to learn much more about one another's situation. Many faculty came to have a deeper appreciation of their students' educational experience. This same insightful, practical perspective has marked Dean MacVicar's choice of issues to engage during her years in this role.

Her suggestions five years ago to link several freshman physics and calculus recitation sections, and to interview a random sample of freshmen in the Class of 1991, were two of several modest interventions having larger consequences in which I participated along with ODUE staff members Margaret Enders, Maureen Horgan, Gregory Jackson, Norma McGavern, and others. This was a most welcomed assignment, since in 1961 I had attended the first year science subjects and interviewed both students and faculty as part of my longitudinal study of the Class of 1965 (*The Hidden Curriculum*, Alfred A. Knopf, Inc., New York, 1971).

Further, in 1980 I had begun to interview again the original 54 students, and by 1987 had spoken at length with 51 of them. (*Literacy and Numeracy: Two Ways of Knowing, Daedalus, Spring 1990, Vol. 119, No. 2, pages 233-256.*)

Both of these ODU projects revealed underlying, interrelated and longstanding problems in our core education. Some of the "findings" were that all those involved in the freshman science core in the mid 1980's - not only the students, but their faculty and recitation instructors - coped with the multiple and often massive demands on their time with "selective neglect," the same pattern as 25 years earlier. There was less consensus on the core's content five years ago than there was in the early 1960's. Yet communication between the faculty teaching freshman physics and math had remained minimal, at best.

The Dean and her office developed strategies for constructive solutions at several levels. Obtaining funds to refurbish long neglected lecture halls sent a significant positive signal to faculty and students. Having Ms. Enders and Horgan hold regular meetings with the core lecturers and their recitation instructors led to serious discussion of the content of freshman core subjects and became a forum to constructively confront educational problems at the level where it mattered most. The ODU's review and participant observation of physics 8.02X, and then 8.01X, conducted by me and Ms. McGavern, were an important instance of both encouraging innovation and learning from the unfolding experience. These courses, developed and taught primarily by Professors John King and Anthony French with Professor Philip Morrison, emphasized having students learn from hands-on experiments supplemented by lectures and problem sets, a significant departure from the lectures, problem sets and occasional demonstrations of 8.01 and 8.02. The faculty involved, the ODU, and the Education Committee in the Department of Physics all saw evidence of active engagement in the learning process for the majority of students in these new courses.

Under the leadership of Dean MacVicar, members of her office have informed relevant members of the Institute about the effectiveness of educational programs soon enough for this understanding to affect decisions on educational practice and policy. Dean MacVicar and her office have listened well, acted wisely on what they learned, and attended to problems and questions of importance that have often been ignored.

Having been concerned with such issues for over three decades, I am impressed that this approach to MIT's undergraduate educational problems and opportunities grows out of real knowledge of the situation and a grasp of the possibilities of improvement in the coming decade. There is reason for optimism that future changes in MIT's heading will be on course.

BENSON R. SNYDER
Professor of Psychiatry, Emeritus

CONCOURSE

Concourse is an alternative program which covers all of the standard curricula, its structure following the core curriculum in terms of lectures, recitations, problem sets and quizzes. Courses are collaboratively planned although separately taught. The difference lies in the class size (limited to 65 students) and the intimacy the students gain with their professors, tutors and each other in respect to their work; and in the relative ease of coordination of the core material, which shows the connections between the sciences, technology and the humanities, and facilitates learning through reinforcement. This communal, structured approach removes many constraints with regard to helping students consult each other, professors and tutors *and vice versa*. Teaching is easier (and more fun!) and tensions are lessened.

Of the three alternative undergraduate programs, Concourse is the most highly structured. It is unique in that all teaching functions, lectures, recitations, reviews, tutorials, grading, informal and social contact of all kinds, are carried out by Concourse faculty or staff at the Concourse classroom, lounges or offices. This arrangement permits a high degree of educational coordination and personal contact (typical of a small school) but retains all of the resources of MIT. To do this, some sacrifices in flexibility are necessary; in particular, there is no flexibility in the choice of courses. The rewards of this approach are many. For instance, the Concourse curriculum is designed to preserve all upperclass options and increases flexibility

after the first year; the advantages in scheduling leave all afternoons totally free in the Fall term and facilitate extracurricular and athletic participation. The latter is probably the reason for the disproportionately large number (in past years) of Concourse students in leadership positions at MIT.

Statistics

Sixty-five students enrolled in Concourse for the fall term. Of these, 33 were male, 32 female, 51% and 49% of the total, respectively.

Six of these students (6 male) were minority students, 9% of the total enrollment.

The spring semester had a total of 49 students, 25 male and 24 female, including in the total 2 minority students (4%).

With regard to academic performance, the Concourse Class of 1989-90 performed, in its sophomore year, approximately as well as the Class of 1993 on the whole, although the scholastic indices for the Concourse Class of 1989-90 as entering freshmen were significantly *below* the mean for the Class of 1993 on the whole. We tabulated this data below:

During Sophomore Year For Concourse Class of 1989-90 (MIT Class '93)

GROUP	Number of students	Average scholastic index	Average personal rating	Median grade pt. average fall term	Median grade pt. average spring term
Students enrolled in Concourse for full year	48	58.6	3.43	4.0 ¹	4.0 ²
Students enrolled in Concourse for Fall Term only	15	46.5	3.45	3.55 ³	3.7 ⁴
MIT Freshmen	982	65.8	3.31	4.1 ⁵	4.2 ⁶

¹ Data on only 46 students. Six students (13%) were flagged for discussion by CAP.

² Grade point data on only 46 students. Five students (11%) were flagged for discussion by CAP.

³ Grade point data on only 15 students. Four students (27%) were flagged for discussion by CAP.

⁴ Grade point data on only 14 students. Four students (29%) were flagged for discussion by CAP.

⁵ Figure represents grade pt. data on 1,095 sophomores and includes all Concourse students.

⁶ Figure represents grade pt. data on 1,090 sophomores and includes all Concourse students.

A possible exception to the above statement is the group of students who remained in Concourse for the fall term only, particularly for the spring term of the second year.

Last year's Concourse students (1989-1990; MIT Class of 1993) entered the the following disciplines:

29 students (63%) entered departments within the School of Engineering;

8 students (17%) entered departments within the School of Science;

1 student (2%) entered the School of Management;

3 students (7%) entered a department within the School of Humanities and Social Science;

5 students (11%) remained undesignated.

Faculty and Staff

The extensive role played by undergraduates in Concourse makes extraordinary demands on the talent, energy and collegiality of the faculty, the core of the community. The senior faculty have over 30 years each of teaching experience, and have been recognized for teaching excellence and commitment by awards or

prizes at some time in their careers. The junior faculty are selected by criteria which include energetic commitment to and competence in teaching.

Members of the Concourse Faculty for 1990-91 were: Professor Robert M. Rose, Department of Materials Science and Engineering; Professor Judah L. Schwartz, School of Engineering and Harvard School of Education; Dr. Helen Grundman and Dr. Minhyong Kim, Department of Mathematics; Dr. Gilbert Whittemore and Dr. Mangol Bayat, Writing Program; Dr. Kevin Rhoads and Massimo Russo, Office of the Provost; and Cheryl Butters, Office of the Dean for Undergraduate Education.

Each term ten MIT undergraduates were employed as teaching assistants, to teach, to run evening tutorials and to run recitations in chemistry, calculus, physics and differential equations.

The Concourse Program was overseen by Professor Rose as Director and by Ms. Butters as Program Coordinator.

Academic Developments

Humanities

The humanities core course, "Introduction to the History of Science," (SP341 in the *MIT Bulletin*) explored the origins of scientific thought in the West, beginning with ancient myths, through the emergence of natural philosophy in ancient Greece, its transmission through Islam to the West, the development of science as a new intellectual and social force in the late 16th and 17th centuries, later developments in chemistry, physics and mathematics, and concluding with the theory of relativity in the 20th century. The development of the understanding of nature was placed within the context of human affairs in general. Besides two general texts on the subject, the course required reading from original sources, including Aristotle, Ptolemy, Copernicus, Kepler, Newton, Lavoisier and Einstein. Additional direct exposure to sources was obtained via guest lecturers such as Cynthia Rose (an Egyptologist on the MIT staff), field trips to local museums and the Collection of Historical Instruments at Harvard University. The presentation was coordinated with the science core; the physics and mathematics of rotational motion had been presented by the time the development of the Copernican system was discussed in the Humanities course.

Our second-term Humanities presentation was SP342, "Islam and Modernity," a twelve-unit HASS-D course. It begins with an introduction to Islamic religion, culture and institutions and the response of Islam to the rise of the West and Western ideas. It ends with an analysis of the conflicts which have arisen between secular nationalist aspirations and fundamentalist Islamic ideals. Originally conceived several years ago as an experiment, this course complements "Introduction to the History of Science" perfectly.

Extracurricular Educational Activities; Independent Activities Period

Last years' experiments during IAP led to three regular seminars during IAP 1991:

1. "Real Physics Made Simple," taught by Dr. Yuri Chernyak, a theoretical physicist. In this seminar each topic began with a simple problem (e.g., running to catch a bus) and then proceeded to grander topics which looked different but in fact had the same basic underlying idea (e.g., Cherenkov radiation) as the familiar problem. This approach was used to explain (besides Cherenkov radiation) the Doppler effect, universal expansion, the Mach cone and other topics.
2. "Some Basic Principles of Physics," also taught by Dr. Chernyak. Some of the most basic and abstract ideas, including invariance, similarity and conservation laws were extensively explored. Examples from physics, chemistry, economics, meteorology, ecology and fluid dynamics were used.
3. "Solving Problems in Science and Engineering," taught by Professor Rose. The objective was to develop problem-solving skills in chemistry, physics, and in general. The arts of approximation and estimation as well as deduction were emphasized.

Regular dinners held in the Concourse Lounge during IAP, and the weekly "physics breakfast" under the auspices of Professor Schwartz were continued throughout the spring term; also, some enrichments (at

breakfast) on the Concourse Chemistry syllabus, including semiconductor materials and technology and the theory of fracture.

Science Core

The core presentations continue the successes of previous years. The major change is that we have reverted to the equivalent of 8.012 in the first term, after two years of 8.01. It was our feeling that the more rigorous version was better intellectual preparation for the second year. Concourse chemistry, essentially a synthesis of 3.091 *Introduction to Solid State Chemistry* and 5.11 *Principles of Chemical Science*, contains the essence of each but is identical to neither. Again, the coverage is paced to connect with, reinforce and illuminate the other core presentations and to encourage further exploration. This presentation serves as a prerequisite for 5.12 *Organic Chemistry* or for any course having 3.091 as a prerequisite.

ROBERT M. ROSE
Director of Concourse

AIR FORCE ROTC

The Air Force Reserve Officer Training Corps (AFROTC) program at MIT provides challenging and comprehensive leadership and academic training for students attending MIT, Harvard, Tufts, and Wellesley. We continue to recruit and commission men and women as 2nd lieutenants in the United States Air Force. Year-end enrollment in AFROTC as of June 1991 was as follows:

	<u>Freshman</u>	<u>Sophomores</u>	<u>Juniors</u>	<u>Seniors</u>	<u>Total</u>
MIT	25	18	15	14	72
Harvard	4	0	1	3	8
Tufts	3	0	6	6	15
Wellesley	0	0	0	0	0
Total	32	18	22	23	95

The assortment of special cadet activities continued unchanged from previous years and included a Freshman Orientation Program emphasizing Air Force knowledge, physical fitness, and drill; the Blue Eagles Drill Team; the Arnold Air Society, a community service organization; an Air Force Dining-In, a formal dinner with guest speaker; and the Tri-Service Military Ball, parade, awards ceremony, and commissioning ceremony at the USS Constitution.

Highlights from AY 90/91 follow:

- The Freshman Orientation Program was run at MIT and Griffiss Air Force Base, New York (a first).
- In the fall term, Prof Meyer lectured and Col Craigie led the recitations for the inaugural offering of 17.471 American National Security Policy to 49 students (24 were non-AFROTC).
- On 17 Oct 90, the MIT faculty voted to allow ROTC to continue on campus while pursuing a program to change the Department of Defense homosexual exclusionary policy.
- Col David Herrelko, former AFROTC alumnus, was the guest speaker at the Dining-In on 2 Nov 90.
- The AFROTC program at MIT received an overall rating of "Excellent" on its Apr 91 Unit Effectiveness Inspection.
- MIT President Vest officiated the Tri-Service Parade on 24 Apr 91.
- The AFROTC program provided MIT cadets with over \$1.08 million for tuition.
- Twelve MIT cadets received commissions as 2nd lieutenants in Jun 91. Two seniors required additional academic work to earn their MIT degrees.

- The Air Force approved time to pursue advanced degrees for all nine from MIT who requested it.
- Maj Levias, SSgt Oliveira, and Ms Park completed another year of dedicated service. New faces were Col Craigie, Maj Lambert, Capt Danley, and TSgt Keller. Departing faces were Col Nelson, Maj Mazerski, Capt Barondes, TSgt Gibson, SSgt Mazzuca, SSgt Shinn, and Ms DeGregori.

COLONEL RONALD P. CRAIGIE
Visiting Professor of Aerospace Studies

ARMY ROTC

The 1990-91 Academic Year was an extremely active and productive one for the Army Reserve Officers' Training Corps (ROTC) Program. The year began with the arrival of two new Officers: the detachment commander, Lieutenant Colonel Gerald Thomas Wellman and the detachment Executive Officer, Major James Arthur Dixon. In early October 1991, the detachment received a Regional Command Inspection (RCI), in which it received a marginally satisfactory rating. As a result, working in close cooperation with MIT, numerous corrective actions were initiated, i.e. upgrade of our physical plant, reallocation of storage space and painting of our hallways and stairwells. Additionally, all administrative shortfalls were corrected. The most significant external distractor to the detachment during the school year was Operation Desert Shield/Desert Storm. The war had no direct impact upon the cadets participating in our program. However, one cadet from Wellesley was required to request a six month Leave of Absence (LOA) to return home and attend to family matters, so that her mother, a reservist, could be deployed. Throughout the duration of the conflict, the detachment received correspondence from numerous alumni, who were either serving in support of the War or knew of former classmates who were. Although none of the detachment's cadre were actually mobilized, all had been subject to call. (Note: A majority of the Army's full time active duty graduate students actually received orders to be executed in the event of full mobilization. They were not otherwise affected.) Finally, this years commissioning on 3 June 1991, took on special significance for the Department of Military Science and our Army commissionees. June third, 1991, marked the 75th anniversary of President Woodrow Wilson's signing of the National Defense Act of 1916. This Act established the Army's Reserved Officer Training Corps (ROTC) as we know it today. Although the Department of Military Science here at MIT dates back to the opening of the school in 1865, the Army ROTC program was not officially established and recognized until 1916.

Enrollment

Over the academic year, a total of 88 students participated in our program, and at year's end, 80 of those students were still enrolled. Of the 80 Cadets, 16 (20%) were females. Of particular note, the top two positions of the cadet battalion (the Commander and the Executive Officers) were both female, additionally indicating our support for Affirmative Action.

A breakdown of year-end enrollment by year and institution is shown below:

	<u>Freshman</u>	<u>Sophomores</u>	<u>Juniors</u>	<u>Seniors</u>	<u>Total</u>
MIT	12	6	13	6	37
Harvard	7	3	9	6	25
Tufts	5	4	1	5	15
Wellesley	0	2	1	0	3
Total	24	15	24	17	80

Of the 36 MIT students enrolled, 27 are currently recipients of Army ROTC scholarships and six others have scholarships pending. These scholarships pay 80% of tuition and 100% of fees; provide a monthly allowance of \$100; and contribute once-a-year textbook allowance of \$450. The value of these scholarships to MIT for school year 1990-91 was \$405,000. We anticipate that for school year 1991-92, approximately 34 MIT cadets will be on scholarship with a value to MIT of approximately \$510,000.

Commissionees

This year the Army ROTC Department commissioned 14 new second lieutenants, six of whom were from MIT. Of the 14, two are entering graduate school, six will be reporting to active duty, and six are serving in the Army Reserve.

Extracurricular Activities

During the year, Army ROTC again sponsored the Annual Tri-Service Awards Banquet with over 120 cadets receiving awards from over 40 different organizations. Representatives of the MIT, Harvard, Tufts, and Wellesley administrations attended the banquet. Dr. Charles Vest, the president of MIT, was the guest speaker. Army ROTC also participated in various Tri-Service events sponsored by the other services such as the Military Ball, athletic competitions, and the Tri-Service Commissioning Ceremony at the USS Constitution.

On- and off-campus learning opportunities both continued to expand. Cadets trained voluntarily at Fort Benning, GA (Airborne); Ft. Campbell, KY (Air Assault); Norwich, Vermont (Cold Weather); and Germany and other U.S. posts (troop leadership). Participation continued strong in the MIT Pershing Rifles Company, a group of both ROTC and non-ROTC students dedicated to the pursuit of military tactical excellence and patriotism.

The ROTC Faculty, Committee, under the chairmanship of Professor Alvin W. Drake, continued to provide timely advice and support of the ROTC programs. Most notable was the Committee's efforts in addressing the contradiction between MIT policy and DOD policy concerning sexual orientation of ROTC students.

LIEUTENANT COLONEL GERALD T. WELLMAN
Professor of Military Science

NAVY ROTC

The mission of the Naval Reserve Officers Training Corps (NROTC) Program at MIT continues as described in previous Reports: This year a total of 42 graduating men and women were commissioned as officers in the Navy and Marine Corps; all of them commenced active Armed Service. Program enrollment just prior to graduation was:

	<u>Freshman</u>	<u>Sophomores</u>	<u>Juniors</u>	<u>Seniors</u>	<u>Total</u>
MIT	27	14	21	23	85
Harvard	17	10	16	13	56
Tufts	6	6	10	9	31
Wellesley	0	1	1	0	2
Total	50	31	48	45	174

The Navy's financial assistance for these students totaled approximately \$2.6 million for the year, including about \$1.3 million for MIT students. Approximately 88% of all NROTC students and 89% of MIT students receive full tuition, payment for books, and monthly stipend.

Enrollment has declined to 174 from the 181 reported last year. Total enrollment would have increased if the class of 1993 had not sustained 24 attrites. This figure represents an unusually high 44% decrease for a class, and we believe it is an anomaly rather than a trend.

Activities

Annual activities and ongoing programs continued as in the past. The biennial Pass-In-Review was held in April with President Vest participating as senior reviewing officer. All three ROTC units participated. The speaker for the tri-service commissioning ceremony held on 3 June aboard USS CONSTITUTION was Vice Admiral J. Paul Reason, Commander, Naval Surface Force, U.S. Atlantic Fleet.

Audits/Inspections

A triennial command inspection, sponsored by our parent headquarters (Chief of Naval Education and Training), was conducted in early October. The inspection was comprehensive and thorough; the results were highly satisfactory. An audit of our Navy budget (Procurement Management Review) was conducted in March with similar results. Our MIT budget account was audited in May, and there were no findings.

Department of Defense Reductions

Reductions in overall Defense spending and in manpower will affect MIT's NROTC Program to a limited degree. We do not expect our student enrollment to change significantly. We do expect, however, to see somewhat smaller numbers of four-year scholarship recipients and increased numbers of three year scholarship students in future entering classes.

Program military staffing will decline slightly as well. In June Captain Robert Sherer stepped down as Professor of Naval Science, and his duties were assumed by Captain Michael Field, who is also Professor of Naval Science at Boston University (BU). Captain Field will divide his efforts between MIT and BU. By September 1992 we expect the Associate Professor of Naval Science and two technical instructors will also have shared responsibilities at both MIT and BU. It is important to note, however, that neither the structure nor the identity of the NROTC Programs at MIT or BU will be substantially changed by these measures.

As part of the Navy's cost-cutting efforts, a nation-wide review of all cross-enrolled NROTC arrangements was made. The arrangement with Wellesley College was determined to be only marginally useful and beginning with the class of 1995, NROTC accessions will be discontinued at that campus.

Affirmative Action

The NROTC Program at MIT makes few hiring decisions. Staff replacements are generally managed by central Navy authority and are subject to US Government affirmative action policy. We are sensitive to affirmative action, equal opportunity and sexual harassment issues as defined by the Department of Defense. A series of workshops designed to reinforce awareness of these matters was held in September for staff and student personnel. As far as we can determine, there have been no incidents involving our personnel on these issues.

CAPTAIN MICHAEL FIELD
Professor of Naval Science

Office of the Dean of the Graduate School

NSF FELLOWS' TUITION SHORTFALL

In last year's report we described a proposal to cap the amount of General Funds that MIT would make available to cover the tuition shortfall associated with graduate students who are supported on various Federal fellowships, most notably the National Science Foundation (NSF) Fellowships. The shortfall results from the gap between the cost-of-education allowance (COEA) provided by these Federal fellowships and MIT's actual tuition, coupled with the requirement that MIT accept the COEA "in lieu of tuition and fees". In previous years that shortfall had been allowed to grow without limit. In the 1989-90 academic year it amounted to about \$2.9 million and was projected to be as large as \$3.5 million for the 1990-91 year.

The new system, which was implemented for the first time in the past year, set the cap on General Funds at \$2.9 million for NSF Fellows supported in the 1990-91 academic year, thus limiting the call on those funds to the previous year's level. The \$2.9 million shortfall account fund was then allocated by the ODGS to individual academic departments on a pro rata basis in proportion to the number of NSF Fellows they had supported during the previous year. In general, these departmental allocations were insufficient to meet the entire departmental shortfall, and departments were given the option of either using their own funds to cover the remaining shortfall or limiting the number of students whose NSF fellowships they would honor. All but one of the departments chose the first option, i.e., they tapped into various departmental and school sources for the remaining funds and were thus able to treat all NSF fellowship recipients in the same manner as in previous years.

The one exception was the Department of Mechanical Engineering, which experienced an unusually large increase in the number of NSF fellowship recipients choosing to enroll at MIT. Several of these students were notified that their fellowships could not be honored and were offered alternative support in the form of research assistantships. At least two of these students chose subsequently to give up their NSF fellowships and enroll at MIT; the others presumably took their NSF support to other institutions.

The number of NSF Fellows finally enrolled at MIT for the 1990-91 academic year was 205 on active status with another 25 on reserve status (i.e., holding their NSF support in reserve for use in a later academic year). The corresponding figures for the previous year were 194 active and 18 on reserve. The increase represented by these figures is within the range we have come to expect in recent years and suggests that our new capping policy did not have a significant impact on the total number of NSF fellows at MIT.

Adoption of the tuition shortfall cap served as a vehicle through which we were able to continue to bring to the NSF's attention our concern over their failure to increase the COEA. Note, for example, that the COEA of \$6,000 which was in effect for the 1990-91 academic year was originally established at that level in 1985. Thus, the COEA remained unchanged during a period in which MIT's 12-month tuition rose from \$14,950 to \$21,200 - an increase larger than the NSF's annual tuition allowance. We were pleased to learn at year's end that the NSF was about to announce a \$1,500 increase in the COEA for the 1991-92 academic year and was considering a policy which would provide biennial increases of \$1,000.

GRADUATE STUDENT SUPPORT AND ADMINISTRATION

During the past year the ODGS continued its regular functions involved in the support and administration of graduate students. These functions include: entry of all graduate fellowship and assistantship data into the Registrar's data base, resolution of discrepancies and enforcement of MIT policies regarding these graduate appointments and awards,

interaction with external fellowship sponsors and enforcement of administrative policies on their behalf, conduct of competition for centrally-administered endowed fellowships, allocation of endowed and similar funds to the academic departments, and processing of petitions covering a myriad of issues. There were no major changes in these activities in the past year; however, it is appropriate to note that although the number of externally-sponsored fellowships and internal petitions continued to grow, the efficiency with which they were administered also improved markedly thanks to the efforts of the ODGS staff.

The ODGS did look into the possibility of establishing a policy of reduced tuition for graduate students who have completed their formal subject and examination requirements. Such policies exist at many other institutions with whom we compete for graduate students and are frequently known as ABD ("All But Dissertation") tuition policies. Our comparison of the ABD policies in effect at other institutions and MIT's tuition policies revealed the following:

- Our non-resident doctoral dissertation status provides about the same level of tuition reduction as is typically available elsewhere and at about the same time in a student's program.
- Students in departments where little financial support is available generally take advantage of non-resident status and its tuition reduction as soon as they become eligible for it.
- The cost of adopting a reduced tuition policy for all graduate students in ABD status would be prohibitive (estimated at more than \$20 million in lost tuition income per year).

For these reasons it was concluded that a general ABD policy is neither necessary nor feasible. However, it was also noted that some of the restrictions in our present non-resident doctoral dissertation status may be unduly severe; we shall examine this issue further in the coming year.

During the 1989-90 academic year, the MIT Commencement Committee determined that a Hooding Ceremony for doctoral degree recipients should be added to the annual graduation exercises, and implemented such a ceremony in June 1990. The Hooding Ceremony was designed to fill the void which had been created several years earlier when the hooding of doctoral recipients was eliminated from MIT's Commencement Exercises. Having successfully launched this new exercise, responsibility for the Hooding Ceremony was then turned over by the Commencement Committee to the ODGS starting with the 1991 event. With considerable assistance from a number of departments' graduate administrators and participation of the entire staff of the ODGS, the 1991 Hooding Ceremony was successfully staged in Rockwell Cage. It seems clear that this ceremony has become an integral part of the Commencement Exercises, and will be an ongoing new responsibility of the ODGS.

The ODGS continued its major role in helping to plan and conduct an Orientation Workshop for New Faculty and Teaching staff. In particular, the ODGS took responsibility for that portion of the workshop directed toward graduate teaching assistants, and was pleased that 146 TAs participated.

AFFIRMATIVE ACTION AND OUTREACH

Sponsored Programs

The *Minority Mentorship Program* experienced an active and successful year. Rondell Milton, a sophomore in Course 6, was selected as this year's Minority Mentor. In this program, the student so honored receives financial assistance in return for services as a mentor who encourages younger students to consider college studies. The mentor is

responsible for developing a proposed plan of action. Mr. Milton developed a project to bring two students from his former Colorado high school to the National Society of Black Engineers' national conference to participate in its pre-college initiative activities.

Additional activities under the Minority Mentorship Program included a program co-sponsored by the MIT Chapter of the National Society of Black Engineers and designed to encourage minority students in local secondary schools to consider college as an option. Approximately 40 junior-high and high-school students from Cambridge and Boston participated in a lecture and practical workshop at MIT on aerodynamics. Following the lecture, the design workshop focused on building paper airplanes and "eggware" products to prevent egg breakage. A competition to discover the most effective designs in each category culminated the workshop.

A third activity was designed to bring minority role models to campus, and focused on minority graduate students and their career options. Four MIT minority alumni, all currently employed as faculty members in historically Black and Latino institutions, returned to talk with graduate students about the realities and opportunities of academic careers and to encourage them to consider this option.

The *Visiting Faculty Program for Historically Black Colleges and Universities* is a cooperative program between MIT and four HBCU institutions: Clark/Atlanta, Spelman, Morehouse and North Carolina A & T. Over the past year, program liaisons were appointed at each campus and several meetings were held in Atlanta, sponsored by foundation supporters. These discussions sought to fashion a strategy for developing productive academic and research based relationships between HBCU faculty and their colleagues at MIT.

The *Minority Summer Science Research Program* continues to enjoy broad acceptance within the School of Science and Whitaker College, and interns continue to report positive developmental research experiences with our faculty and advanced graduate students. Every graduating senior from the 1990 program has been admitted to a graduate degree program for the 1991/92 academic year, with one accepted into MIT's Biology Department. The program is highly successful and is emulated widely. However, the growing availability of summer research internships in both industry and academia have sharply increased the competition for students. For future programs, we plan to begin recruiting potential interns earlier. Also, raising additional operating and endowment funds will be a major priority for the coming year.

Recruitment and Outreach

The major recruitment activity of the past year centered on arming graduate departments with additional information to assist their recruiting campaigns. Assistant Dean Margo D. Tyler developed a Resource Guide consisting of detailed listings of historically Black and Latino colleges, faculty and administrative contacts at these institutions, fact sheets, and other useful information. The Guide was distributed to departmental graduate admissions officers, and Dean Tyler visited departmental admissions committee heads, using the Guide to catalyze discussions about their recruitment activities.

In related activities, the ODGS conducted its annual seminar to encourage our minority undergraduates to plan for matriculation into graduate degree programs. The seminar was held in the living groups, focused on presentations by current graduate students, and was followed by a lively question/answer session. Also, a number of current graduate students volunteered to recruit at various colleges and universities in order to assist their departments in locating and attracting students of color to MIT.

Finally, the ODGS continued its support for various cultural activities on behalf of the minority community. For the past year, this included partial support for the annual Kwanza Celebration, the Ebony Affair Dance, receptions for women and minority graduate

students, visiting guests and speakers, and cultural events for Latino and Native American students. Such activities have become a large and growing part of our program of support for underrepresented groups and will require the commitment of additional financial resources. In particular, the growing needs of women graduate students demand more attention and resources, and will be a major focus of activities for the coming year.

INDIVIDUAL ACTIVITIES

Individual staff members of the ODGS were active in various Institute committees and outside professional activities. Dean Perkins continued to serve on an ad hoc Institute committee concerned with the academic calendar and related academic issues. He also continued to play an active role in the Association of Graduate Schools (AGS), where he served on the Executive Committee and on the Working Group on Federal Graduate Education Policy. Dean Perkins and Associate Dean Isaac M. Colbert continued their leadership roles on the Institute's International Scholarship Committee.

Dean Colbert was recently named Trustee of the Chapel Hill-Chauncy Hall School in Waltham, became co-chair of the MIT Martin Luther King Memorial Celebration Committee, and continued his leadership role in the Association of African American Administrators at MIT. He also continued in his roles as Treasurer of the Cambridge Partnership for Public Education and coordinator of data gathering and exchange for the DWARF institutions.

Congratulations are in order for Dean Tyler, who was awarded a Master's Degree in Public Administration from Harvard University's Kennedy School of Government this year. She continued to represent MIT at the National Association of Women Deans and other regional and national organizations, and chaired the professional development committee of the Association of African American Administrators at MIT.

COMMITTEE ON GRADUATE SCHOOL POLICY

During the past year, the CGSP conducted two program reviews. The first related to a continuation of the Masters in Industry Experiment in the Department of Electrical Engineering and Computer Science. This program was given an initial three-year approval by the CGSP and admitted its first class in the fall term of the 1988-89 academic year. The program was designed to allow selected employees of participating companies to pursue their Masters degrees by taking subjects on campus on a part-time basis, then performing a thesis at the company under faculty supervision. Our review indicated that participation in the program had developed slowly and that relatively few MIT undergraduates had found their way into the program. Nonetheless, the EECS Department argued that there was a good basis for continuing the program in an experimental mode, especially in view of the likely synergy between the program and the department's developing proposal for a First Professional Degree in EECS. The CGSP approved a three year continuation of the program.

The CGSP also conducted a preliminary review of the Doctoral Program in the History and Social Study of Science and Technology, which is a joint offering of the Program in Science, Technology, and Society, and the faculties of History and Anthropology/ Archaeology. This program was approved by the CGSP, the MIT faculty, and the Corporation during the 1987-88 academic year, and the first class enrolled in September 1988. The objective of this program is "to prepare students for advanced work on the history and social relations of science and technology, and specifically for teaching and research careers in higher education, museum work, and public service". The program's leadership has also stated an intention "to become the outstanding program of its kind in the nation". The program was originally approved for a five-year period but was brought forward at this time so that the CGSP could ascertain its progress and prospects for subsequent permanent approval. The CGSP review was enthusiastically positive. The program was found to be progressing very much in accordance with its original plans and to be on course for permanent status in the future.

The CGSP took note of the fact that its long-standing policy governing theses done in absentia had inadvertently been abandoned some years ago when the policy on non-resident doctoral dissertation status was adopted. Since these two policies apply to distinctly separate situations, the CGSP reestablished a statement of policy relating to thesis research to be done in absentia. The resumed policy, which will appear in the 1991/92 issue of the Graduate School Manual, recognizes that there are occasions where research away from the Institute is essential or desirable, but notes that it is the responsibility of the student's department to establish that there are compelling educational reasons to do so. The CGSP policy is designed to ensure that the department and the ODGS are aware of all students who are working in absentia, and that the educational benefits to the student are clear.

The CGSP continued to address the problem of students whose registration for thesis has extended beyond reasonable limits and whose current rate of progress toward completing the thesis is not adequate. A specific issue arose in this regard when one department changed the thesis grades of several such students from "J" to "U" in order to provide justification for issuance of formal Dean's warnings. This incident led to extensive CGSP discussion, and clarification of the "U" grade, the changing of grades by a departmental graduate committee, and the issuance of Dean's warnings.

In a related manner, the Department of Mechanical Engineering addressed the problem of increasing time to degree completion by endorsing a statement that establishes a norm of three terms for completion of the Master's degree in that department.

The CGSP of course performed its usual functions related to the review of academic performance, the termination of enrollment in a few instances, and the recommending of graduate degrees.

My colleagues in the ODGS and I wish to express our thanks and appreciation to members of the CGSP for their service during the past year. A special "thank you" is extended to the following members who will be replaced in the coming year: Ole Madsen (Civil Engineering) replaced by Eduardo Kausel, David J. Epstein (EECS) replaced by Frederic R. Morgenthaler, Frederick A. Frey (EAPS) replaced by Charles Counselman III, William Wheaton (Economics) replaced by Ann Friedlaender, Gordon M. Kaufman (Management) replaced by Dan Nyhart, and Sylvain Bromberger (Linguistics and Philosophy) replaced by Richard Cartwright (fall term only).

GRADUATE SCHOOL STATISTICS

Important statistics concerning the Graduate School are presented in Tables I-V and Figures I-III, which follow. The format and content of Tables I-IV are essentially identical to those that were presented in the two previous reports.

The enrollment figures in Table I show no major changes from the two previous years. The total graduate student enrollment grew at a rate of less than 1% per year over that period and was still at a level below the peak years of 1985 and 1986. There were very small increases in the enrollment of women and minority students. The percentage of women students in the Graduate School had been fixed at about 20% for the last several years; however, the data in Table I and Figure I show that that figure has now increased to 21.7%. Whether this is simply a temporal fluctuation or is the start of an upward trend cannot yet be determined. The enrollment of underrepresented minority students (Table V and Figure III), which also exhibits a small increase over the past two years, is even more problematic; the increase of 12 students is so small as to be "in the noise". About the only positive note is that any increase is preferred to the decrease which we reported in last year's report. The enrollment of foreign national students, on the other hand, appears to be rising slowly at approximately the same rate as for women students (Table V and Figure II).

The data in Table II indicate that the total amount of graduate student support has just about kept pace with increases in tuition, stipends, and total enrollment. The figures again dramatically indicate the extent to which we are dependent on sponsored research for well over 50% of all graduate student support. The data also show a significant growth in the difference between the number of awards/appointments actually made to graduate students and the equivalent number of fully-supported students these awards/appointments represent. The growth in this difference is, we believe, explained by the growing tendency of many departments to make supplementary, partial awards/appointments for their students. As a result, the ODGS finds that the total number of transactions made on behalf of graduate students is growing much faster than is the graduate enrollment.

A surprising growth in the number of graduate applications for admission is reflected in the figures in Table III. Despite demographic data, which imply that we might expect a decline in applications, the 9,443 applications reported in Table III represent an increase of 570 applications (6.4%) over the last two years. These increases were distributed over all MIT departments.

The data for degrees awarded, which appear in Table IV, show little change in the number of doctorates and modest increases in the number of Masters degrees consistent with the enrollment growth noted above.

FRANK E. PERKINS

	<u>FOREIGN</u>	<u>WOMEN</u>	<u>MINORITY</u>	<u>NEW</u>	<u>NON-RESIDENT</u>	<u>TOTAL</u>
SCHOOL OF ARCHITECTURE & PLANNING	112	154	47	146	43	436
Architecture	64	79	15	81	13	264
Urban Studies & Planning	48	75	32	65	30	172
SCHOOL OF ENGINEERING	798	376	64	495	25	2246
Aeronautics & Astronautics	68	19	3	50	2	209
Chemical Engineering	84	43	12	38	3	217
Civil Engineering	143	49	5	70	6	260
Electrical Eng & Computer Science	140	126	24	130	6	664
Materials Science & Engineering	71	53	6	33	1	185
Mechanical Engineering	146	53	10	103	1	400
Nuclear Engineering	75	16	4	25	2	151
Ocean Engineering	71	17	0	46	4	160
SCHOOL OF HUMANITIES & SOCIAL SCIENCES	124	108	10	75	50	372
Economics	48	32	6	32	6	135
Linguistics & Philosophy	35	18	0	12	2	60
Political Science	40	54	4	28	42	165
Science, Technology & Society	1	4	0	3	0	12
SCHOOL OF MANAGEMENT	259	143	20	322	7	669
SCHOOL OF SCIENCE	319	271	27	193	18	1109
Applied Biological Sciences	6	11	0	0	0	23
Biology	25	85	1	34	2	203
Chemistry	51	70	5	44	2	255
Earth, Atmospheric & Planetary Sci	59	44	2	27	1	167
Mathematics	63	15	2	29	11	125
Physics	106	34	14	54	2	311
Toxicology	9	12	3	5	0	25
WHITAKER COLLEGE	12	9	2	9	0	56
Brain & Cognitive Sciences	12	8	2	9	0	52
Health Policy & Management	0	1	0	0	0	4
HEALTH SCIENCES & TECHNOLOGY	4	3	1	0	0	18
TOTAL GRADUATE ENROLLMENT	1628	1064	171	1240	143	4906
CATEGORY AS % OF TOTAL	33.2%	21.7%	3.5%	25.3%	2.9%	

"Minority" refers to underrepresented minorities (i.e., Black Americans, Puerto Ricans, Mexican Americans, and American Indians).

"New" refers to new graduate students enrolled for the first time in the Graduate School.

"Non-Resident" refers to students who are in non-resident doctoral dissertation status.

TABLE I: GRADUATE ENROLLMENT STATISTICS, FALL 1990

<u>CATEGORY OF SUPPORT</u>	<u>NUMBER OF STUDENTS (ACTUAL)</u>	<u>NUMBER OF STUDENTS (EFS)</u>	<u>TUITION FALL TERM</u>	<u>TUITION SPRING TERM</u>	<u>STIPEND FALL TERM</u>	<u>STIPEND SPRING TERM</u>	<u>TOTAL ACADEMIC YEAR SUPPORT</u>
Research Assistantships	2,678	2,012	15,693	15,419	9,587	9,493	50,192
Teaching Assistantships	847	450	3,514	3,222	2,369	2,115	11,221
Graduate Instructorships	95	0	0	3	135	91	229
Federal Fellowships/Traineeships	241	133	1,039	1,027	1,168	1,154	4,389
MIT Endowed Support (Dept'l)	155	72	561	495	223	202	1,481
MIT Endowed Support (ODGS)	95	56	433	372	108	100	1,012
MIT General Support	900	399	3,111	3,080	1,047	958	8,196
Industrial Fellowships	575	207	1,615	1,793	1,150	1,368	5,926
Foundation Fellowships	289	189	1,477	1,390	713	646	4,227
Billed by MIT to Outside Sponsors	427	350	2,731	2,441	0	0	5,172
TOTAL IDENTIFIED SUPPORT	6,302	3,869	30,175	29,241	16,501	16,127	92,045

Note: Many students receive partial support from one or more sources. Therefore, the total number of students receiving support from any source may exceed the total number of graduate students. The term "EFS" refers to an equivalent number of fully supported students, and is computed by dividing the total fall term tuition support by the fall term tuition of \$7800 per student.

TABLE II: SOURCES AND AMOUNTS OF GRADUATE STUDENT SUPPORT, 1990-91 ACADEMIC YEAR

(DOLLAR AMOUNTS REPRESENTED IN THOUSANDS)

	<u>NUMBER OF</u> <u>APPLICANTS</u>	<u>NUMBER</u> <u>ADMITTED</u>	<u>RATIO</u> <u>ADMIT/APPL</u>	<u>NUMBER</u> <u>REGISTERED</u>	<u>RATIO</u> <u>REG/ADMIT</u>
SCHOOL OF ARCHITECTURE & PLANNING	991	280	0.28	157	0.56
Architecture	612	143	0.23	86	0.60
Urban Studies & Planning	284	137	0.48	71	0.52
Real Estate Development*	95				
SCHOOL OF ENGINEERING	3417	981	0.29	458	0.47
Aeronautics & Astronautics	265	126	0.48	50	0.40
Chemical Engineering	224	79	0.35	42	0.53
Civil Engineering	331	202	0.61	75	0.37
Electrical Eng & Computer Science	1599	211	0.13	114	0.54
Materials Science & Engineering	195	54	0.28	30	0.56
Mechanical Engineering	558	202	0.36	96	0.48
Nuclear Engineering	96	52	0.54	25	0.48
Ocean Engineering	91	55	0.60	26	0.47
Technology & Policy*	55				
Transportation Studies*	3				
SCHOOL OF HUMANITIES & SOCIAL SCIENCES	858	194	0.23	77	0.40
Economics	440	64	0.15	31	0.48
Linguistics & Philosophy	152	29	0.19	12	0.41
Political Science	231	94	0.41	31	0.33
Science, Technology & Society	35	7	0.20	3	0.43
SCHOOL OF MANAGEMENT	2045	371	0.18	268	0.72
Master's Programs	1618	344	0.21	250	0.73
Doctoral Program	349	27	0.08	18	0.67
Operations Research*	78				
SCHOOL OF SCIENCE	1903	487	0.26	185	0.38
Biology	471	77	0.16	37	0.48
Chemistry	381	128	0.34	42	0.33
Earth, Atmospheric & Planetary Sci	183	57	0.31	23	0.40
Mathematics	280	53	0.19	30	0.57
Physics	588	172	0.29	53	0.31
WHITAKER COLLEGE	215	29	0.13	17	0.59
Brain & Cognitive Sciences	179	17	0.09	11	0.65
Toxicology	36	12	0.33	6	0.50
HEALTH SCIENCES & TECHNOLOGY	14	2	0.14	1	0.50
INSTITUTE TOTALS	9443	2344	0.25	1163	0.50

* Applicants to these programs who are subsequently admitted are included in a departmental admissions total. For example, applicants to the Real Estate Development Program are admitted to the Department of Architecture or the Department of Urban Studies and Planning, and are tabulated in the admissions statistics of one or the other of those two departments.

TABLE III: GRADUATE APPLICATIONS AND ADMISSIONS STATISTICS, FALL 1990

NUMBER OF INDICATED DEGREES

	<u>Ph.D.</u>	<u>Sc.D.</u>	<u>Engineers</u>	<u>Masters</u>	<u>Total</u>
SCHOOL OF ARCHITECTURE & PLANNING	15	-	-	164	179
Architecture	7	-	-	92	99
Urban Studies & Planning	8	-	-	72	80
SCHOOL OF ENGINEERING	206	25	41	570	842
Aeronautics & Astronautics	14	1	0	67	82
Chemical Engineering	27	5	0	39	71
Civil Engineering	17	3	3	80	103
Electrical Eng & Computer Science	52	0	19	164	235
Materials Science & Engineering	28	9	0	26	63
Mechanical Engineering	37	4	1	129	171
Nuclear Engineering	18	3	1	26	48
Ocean Engineering	13	0	17	39	69
SCHOOL OF HUMANITIES & SOCIAL SCIENCES	45	-	-	12	57
Economics	26	-	-	0	26
Linguistics & Philosophy	11	-	-	0	11
Political Science	8	-	-	12	20
Science, Technology & Society	0	-	-	0	0
SCHOOL OF MANAGEMENT	19	-	-	357	376
SCHOOL OF SCIENCE	167	4	-	22	193
Applied Biological Sciences	5	0	-	1	6
Biology	27	1	-	1	29
Chemistry	39	0	-	3	42
Earth, Atmospheric & Planetary Sci	25	3	-	9	37
Mathematics	27	0	-	1	28
Physics	44	0	-	7	51
WHITAKER COLLEGE	12	-	-	2	14
Brain & Cognitive Sciences	7	-	-	2	9
Toxicology	3	-	-	0	3
Health, Policy & Management	2	-	-	0	2
HEALTH SCIENCES & TECHNOLOGY	3	-	-	0	3
TOTAL GRADUATE DEGREES	467	29	41	1127	1664

These figures include 26 graduate degrees awarded through the MIT-Woods Hole Oceanographic Institution Joint Program as follows: 14 PhD's (3 in Engineering, 11 in Science), 5 Engineer's, and 7 Master's Degrees (3 in Engineering, 4 in Science).

TABLE IV: GRADUATE DEGREES AWARDED IN ACADEMIC YEAR 1990-91

<u>ACADEMIC YEAR</u>	<u>NUMBER OF WOMEN</u>	<u>PERCENT WOMEN</u>	<u>NUMBER OF FOREIGN NAT.</u>	<u>PERCENT FOREIGN NAT.</u>	<u>NUMBER OF MINORITIES</u>	<u>PERCENT MINORITIES</u>	<u>TOTAL ENROLLMENT</u>
1973	304	9.1%	927	27.9%	108	3.2%	3,328
1974	318	9.5%	954	28.4%	121	3.6%	3,358
1975	405	11.7%	970	28.0%	151	4.4%	3,468
1976	487	13.5%	1,037	28.8%	155	4.3%	3,603
1977	546	14.5%	1,059	28.1%	178	4.7%	3,774
1978	559	14.6%	1,151	30.1%	157	4.1%	3,824
1979	606	15.4%	1,145	29.0%	147	3.7%	3,944
1980	684	16.5%	1,219	29.4%	150	3.6%	4,146
1981	779	17.8%	1,283	29.3%	174	4.0%	4,384
1982	828	18.2%	1,347	29.7%	140	3.1%	4,541
1983	856	19.1%	1,418	31.6%	145	3.2%	4,489
1984	914	19.7%	1,439	31.1%	143	3.1%	4,631
1985	981	20.6%	1,449	30.5%	141	3.0%	4,757
1986	981	19.9%	1,658	33.7%	139	2.8%	4,920
1987	987	19.8%	1,497	30.1%	144	2.9%	4,979
1988	929	19.2%	1,441	29.8%	154	3.2%	4,832
1989	963	20.0%	1,498	31.1%	159	3.3%	4,822
1990	1,064	21.7%	1,628	33.2%	168	3.4%	4,909
TOTALS	13,191	17.2%	23,120	30.1%	2,674	3.5%	76,709

TABLE V: WOMEN, FOREIGN NATIONAL AND MINORITY ENROLLMENT, AY1973 TO AY1990

FIG. I

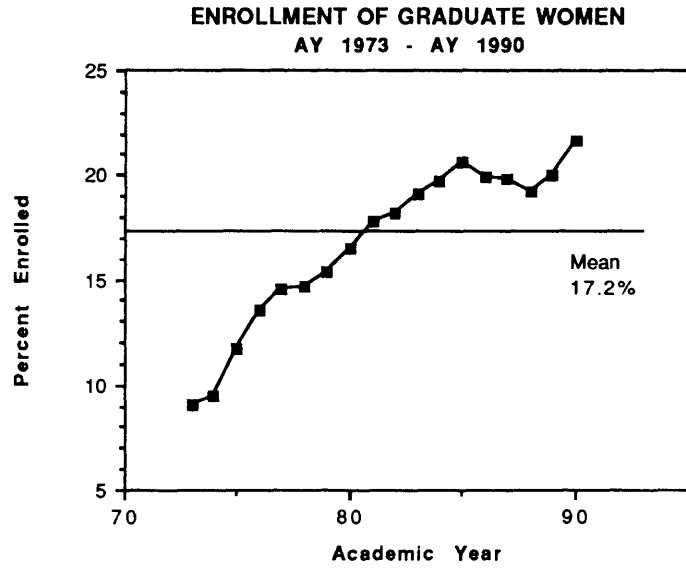


FIG. II

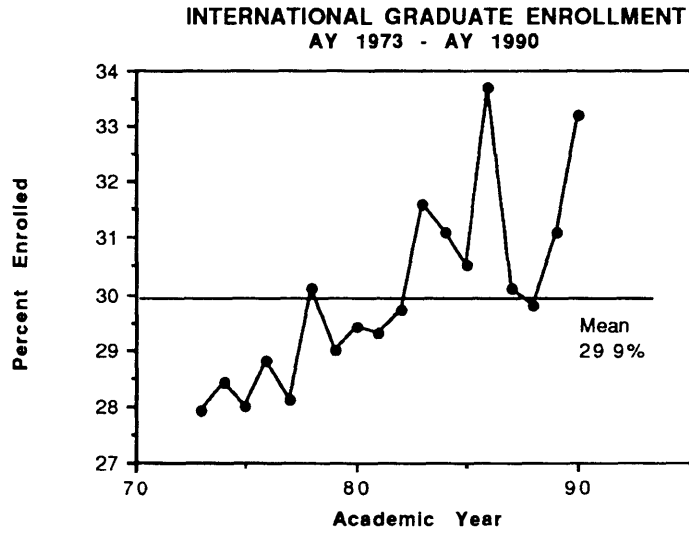
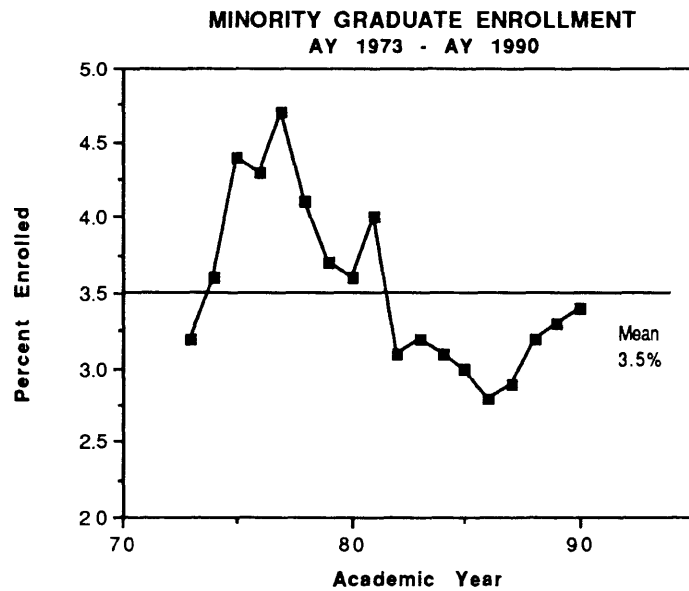


FIG. III



Lowell Institute School

BACKGROUND

The Lowell Institute School (LIS) was established at MIT in 1903 to provide evening instruction in technical subjects for residents of the Boston area. Today the School continues this tradition by offering subjects in the areas of modern technology which are not readily available at other evening institutions. Entry-level courses require an adequate high school preparation, and the more advanced instruction is geared to the practicing technician who has an Associate degree or equivalent experience.

Programs of study range from single subjects designed to broaden job skill levels to comprehensive study of new technological areas in preparation for employment in a new field. There is a strong emphasis on practical aspects and development of careful experimental technique combined with sufficient theory to provide an adequate foundation of understanding. Certificates are awarded to those who satisfactorily complete a course. In addition, students who complete a program of courses may earn a Certificate in Electronics Technology.

CURRICULUM

During 1990-91, LIS enjoyed a ten percent increase in enrollment, due in part to the new, professionally designed *Catalog*. The School offered 37 different courses in analog and digital electronics, microprocessors, electronic imaging and machine vision, computer literacy, computer programming in BASIC and C, drafting, geometric dimensioning and tolerancing, computer aided drafting and circuit board design, alarm technology, housebuilding, and review courses to prepare mechanical engineers for the Engineer-In-Training and Professional Engineer examinations. In addition to refresher courses in mathematics, elementary calculus was included in the curriculum.

New elective courses were introduced in electronics, computer applications, and computer aided drafting. While introductory courses and subjects on the IBM disk operating system continued to be popular, specific applications, such as WordPerfect and dBase III Plus, did not attract sufficient students and were phased out.

A seven-week summer program meeting twice weekly was introduced this year to respond to the heavy demand for computer instruction. Fifty eight students enrolled in courses in AutoCAD, Lotus 1-2-3, computer literacy, and the IBM disk operating system.

AFFIRMATIVE ACTION

LIS admitted a total of 932 students to its courses in 1990-91. Of those enrolled, 82 percent successfully fulfilled the certificate requirements. Among those who completed courses were 98 MIT employees and six MIT students. Thirteen students earned the Certificate in Electronics Technology, and three students earned the Certificate in Drafting Technology. Twenty-two percent of the students were women who desire to enter or to improve their positions in technical fields. The instructing staff of 27 includes four members of minority groups.

SUMMARY

The past academic year has again seen LIS expand its program of unique courses which no other Boston area school can match. The high percentage of students who successfully complete their courses indicates that both the subjects offered and the level of instruction are well matched to their needs.

BRUCE D. WEDLOCK

New Dean of Graduate Students at WHOI

Effective August, 1990, Dr. John W. Farrington assumed the dual role of Associate Director for Education and Dean of Graduate Students at the Woods Hole Oceanographic Institution (WHOI). Dr. Farrington was a Senior Scientist in the Chemistry Department at WHOI between 1971 and 1988 and has most recently served as Director of Environmental Sciences at the University of Massachusetts, Boston.

NEW PROGRAMS**MIT/Woods Hole UROPs**

Effective June, 1991, a formalized UROP (Undergraduate Research Opportunities Program) was initiated between MIT and WHOI. This makes use of the existing MIT UROP program to facilitate interaction between WHOI scientists and MIT undergraduates. The program will be utilized primarily in summer, but we hope that MIT students will also see it as an opportunity for interesting activities during Independent Activities Period (IAP).

Project Athena

Project Athena was extended to include WHOI in November 1991. Joint Program students can now experience seamless computing between the two campuses. The cluster at the WHOI facility, 85 miles from MIT, has four Athena workstations, a printer and a file server, and is accessed via microwave link.

ADMISSIONS STATISTICS

Enrollment in the Joint Program increased 12 percent - from 125 in 1989-90 to a level of 140 for 1990-91. The projected enrollment estimate for September, 1991 is 147 students, with 20 in Chemical Oceanography, 24 in Marine Geology and Geophysics, 25 in Biological Oceanography, 43 in Oceanographic Engineering, and 35 in Physical Oceanography.

There were 158 applicants to the Joint Program for 1991-92, a 17% increase over last year. Fifty-five students were admitted to the program; of these, 34 (62%) accepted our offer of admission. Women comprise 38 percent of the entering class. Of the incoming students, all but five will be doctoral candidates, and four will be minorities.

JOINT PROGRAM GRADUATES

Overall, the Joint Program graduated 21 students in 1990-91; of these, 12 received the doctorate, four received the master's degree, three received the engineer's degree, and two received dual engineer's and master's degrees. The breakdown by discipline is as follows: Chemical Oceanography (one); Biological Oceanography (two); Marine Geology and Geophysics (three); Physical Oceanography (eight); and Oceanographic Engineering (seven).

SALLIE W. CHISHOLM

Summer Session

Special Summer Programs

The Summer Session Office administers an extensive series of one- and two-week special programs for professional men and women who wish to keep pace with developments in their fields. This activity has prospered each summer since its initiation in 1950. Current information on subjects and registrations is as follows:

Summer 1989: 1800 registrations in 72 special programs by 1750 individuals

Summer 1990: 1789 registrations in 78 special programs by 1755 individuals

Foreign students comprised approximately 12 percent of this registration.

Regular Students

Graduate students comprise 87 percent of the student body during the summer. The 1990 registration of 3,136 students was a decrease from 3,146 in 1989.

Upward Bound Program

The MIT/Wellesley Upward Bound Program is a year-round, co-educational, multi-racial, college preparatory program for high school youth who reside or attend school in Cambridge. Currently in its twenty-fourth year, the Program serves 70 academically promising young men and women from disadvantaged backgrounds. The goal of Upward Bound is twofold: (1) to motivate client high school youths such that they persist on to post-secondary education; and, at the same time, (2) to provide them with the fundamental skills necessary for success at the collegiate level.

To a large extent, the Program is influenced by the research done by psychologist Kurt Lewin and his associates. Lewin's hypothesis was that ego growth and academic performance were closely related. Moreover, he concluded that a developing ego needs to experience success in a warm and personal, structured environment for greatest development, in both a personal and social sense. Lastly, it was determined that this personal and social growth could be achieved through intervention outside of the institutions of family and school.

Upward Bound, through its year-round academic and counseling support programming, represents such an intervention. It has long been established that the effects of failure can be reversed through gradual structured achievement. Moreover, the result of the increasing success is a corresponding increase in the individual's level of aspiration. Upward Bound has met with good success (90+ percent of college placement of graduates and 70 percent retention of participants) over much of its twenty-four year history through application of Lewin's theory and careful attention to the impact of Program expectations.

Since much of what students think they can achieve is directly related to what others think they can do, the participants' perceptions of their abilities are, to a significant degree, determined by staff expectations. Thus, and largely due to this quasi parenting relationship, the Program is able to exert a positive influence upon its participants such that their academic persistence continues to increase which results in enhanced college enrollments.

The following is an overview of the Program's operational phases:

SUMMER PROGRAM

The six week summer program, conducted in residence at Wellesley College, is designed to provide the participants with a rigorous academic experience. Classes are taught by experienced high school teachers, and graduate and undergraduate students from MIT, Wellesley College and other local colleges and universities. Upward Bound participants must enroll in three classes, each of which meets for an average of five and one-half hours per week, with three additional hours of supervised study. Also, participants may request or be assigned to tutorials whenever the need arises. Each participant is required to enroll in a Mathematics course, an English course and an elective course (Social Studies or Science). Science electives include; biology, chemistry, physics and computers while Social Studies address United States, Black and World Histories. The Mathematics courses range from arithmetic to calculus and Language Arts courses cover basic English and grammar through research paper writing and literature. Lastly, due to an agreement with the Cambridge Public Schools, students may receive summer school credit for failed courses taken for review.

ACADEMIC YEAR PROGRAM

The academic year program located at MIT, while somewhat less intense due to our after-school operation, is as equally important in the educational development of participants. Building upon the motivation and enthusiasm developed during the summer, the academic year program is designed to assist and support the participant while in school. To accomplish this task, the following programs,

staffed primarily by MIT and Wellesley College students when appropriate, (We continually strive to maintain MIT and Wellesley College students participation through our continued involvement as a pre-practicum site for the Wellesley College Teacher Certification Program and through various outreach efforts.) have been developed:

Tutoring and Study Skills

The Upward Bound office is open for study, on a drop-in basis, four days a week: Monday and Thursday from 3:00 to 6:00 pm and Tuesday and Wednesday 3:00 to 8:00 pm. Tutors are available to assist participants with homework problems in addition to meeting individuals and/or small groups for specific content area tutorials.

Classes and Workshops

The Program offers classes in Mathematics and Language Arts to supplement the instruction received at the target school. Also, academic workshops are offered to address more specialized participant needs (e.g., SAT preparation, computers, foreign language, etc.).

Counseling

In an effort to help participants cope with the myriad of problems; academic, social, family, etc., the Program offers counseling support in the areas of guidance, college, career and personal adjustment.

Cultural and Recreational Activities

The Program provides numerous field trips which have as their purpose, the intellectual, social and cultural development of the participants. Some of the trips have visited; the Museum of Science, the New England Aquarium and the Computer Museum.

COLLEGE REPORT: CLASS OF 1991

One hundred percent of the Program's graduating seniors have enrolled in the following institutions: Elms College, Fitchburg State College and Hampshire College.

RONALD S. CRICHLAW

Office of the Dean for Student Affairs

INTRODUCTION

This has been a year of transition in the Office of the Dean for Student Affairs (ODSA). The changes in the leadership of ODSA and of the Institute present an opportunity to consider possibilities for the future in new ways. I have devoted much of the year to understanding and examining the current responsibilities and functions of the various parts of ODSA. Plans for the future are only beginning to take shape as the year ends.

Some modest reorganization of the Office has taken place and we have added staff in response to urgent needs in the International Students Office and in the Office of Minority Education. Fortunately, it has been a year of relatively little turnover in staff and this has helped to make it possible to continue to manage the wide range of activities and responsibilities which characterize ODSA without interruption despite the change in leadership.

The reports which follow attest to the professional competence and commitment of the staff of ODSA. In order that this wide range of activity could be carried out effectively it was vital that there be a group of people of exceptional capability with the willingness to do all that was necessary without regard to time spent or nominal job descriptions. Dean Shirley M. McBay left an outstanding staff for her successor and I am extremely grateful.

I would like to particularly note the exceptional efforts made by the ODSA staff in response to activities on campus related to the Gulf War. Their response was sensitive to students' needs and attitudes, constructive in resolving conflict, and vital toward preserving an atmosphere in which differing views and convictions could be expressed and understood. Only those who were present will appreciate the time involved and the effort expended but we can all appreciate that a situation which could have been divisive and destructive for the Institute was instead a time of coming together in a positive way.

It was a good year and the future promises to be exciting and satisfying—I'm looking forward to it.

ARTHUR C. SMITH

CENTRAL ADMINISTRATION

The Central Section provides administrative services and facilities support to the entire Office of the Dean for Student Affairs. It also houses the Public Service Center and the statistical research services of the Office. During this year the organization of the section has been formalized and Marilyn Bodnar was appointed section head.

The development of the computer services available to the Office has continued with expansion of the internal mail service and the acquisition of additional, more powerful computers. These allow for more effective operation in several areas of the Office giving additional capability in publication and in handling large data bases.

The staff support to faculty committees, in particular the Committee on Discipline and the Committee on Student Affairs, has been shifted to the Central Section. The activities of the Committee on Discipline have been unusually substantial this year and the shift has relieved some of the stress felt in the Student Assistance Services Section.

Public Service Center

The Public Service Center (PSC) has finished its second year and has been instrumental in promoting public service and providing opportunities to MIT students. The new location on the main corridor has been helpful in calling attention to the PSC's activities.

The PSC again sponsored the *Giving Tree* project which provided holiday presents to over 1000 underprivileged children in the Boston/Cambridge area. Seventeen campus organizations joined with PSC in this successful effort.

The PSC joined with UASO, the Department of Political Science and the Context Initiative to organize the Spring term seminar, *Cambridge, Politics, and the MIT Student*. Students participated in classroom discussions about political theory and worked at least six hours a week in community service internships in Cambridge.

The PSC has continued to coordinate the work of a variety of student organizations which carry out public service projects, to refer individual students to opportunities for service in Boston and Cambridge and to publicize public service throughout the Institute.

Affirmative Action Successes and Objectives

The ODSA continued to maintain a strong commitment to Affirmative Action during the year with a staff that was 19 percent minority and 33 percent male. The following table reflects the race/ethnicity and gender profile, as of June 30, 1991 of the 48 full- and part-time staff within the ODSA.

	Minorities	Non-Minorities	Total
Administrative & Academic Staff			
Male	2	10	12
Female	4	16	20
Subtotal	6	26	32
Support Staff			
Male	1	3	4
Female	2	10	12
Subtotal	3	13	16
TOTAL	9	39	48

The 6 Black employees on the administrative staff included 2 men and 4 women. Of the 3 minority staff among the 16 support staff, there was 1 Puerto Rican male and two females, 1 Asian and 1 Black.

During Fiscal Year 1991, the 4 new full-time persons hired included 1 female and 2 minority males. While the Office of Minority Education has been successful in identifying a Puerto Rican male to assume the position of Assistant Director in August 1991, the ODSA would still welcome the presence of an Asian American on the administrative staff.

MARILYN BODNAR
STEVEN BURKE
ALBERTA LIPSON

VIRGINIA SORENSON
BETTY SULTAN

UNDERGRADUATE ACADEMIC SUPPORT

The Undergraduate Academic Support (UAS) Office coordinates the freshman and undesignated sophomore advising programs, oversees the orientation programs for all new undergraduates, and serves as academic information and general academic counseling center for students, faculty members, and departments. The office also serves as the administrative support structure for the Committee on Academic Performance (CAP), Undergraduate Seminars, the January Independent Activities Period (IAP), the Wellesley-MIT Exchange Program, and the MIT Colloquium.

1990-91 was a good year for UAS. Developments worth special notice included innovative programming for Residence/Orientation, clear progress toward enhancing academic aspects of IAP, closer productive collaboration with the Office of the Dean for Undergraduate Education, and unprecedented success in recruiting faculty to lead Freshman Advisor Seminars for the coming year.

The year's activity in each of the major UAS programs is summarized below.

Freshman Advising Program

There were 225 freshman advisors for the academic year 1990-91, including: 128 faculty; 13 instructors/lecturers; 11 research staff members; 16 graduate students; and 57 administrators. Some 205 undergraduates worked with these advisors as associate advisors. As in recent years, the freshman advising system displayed a healthy pluralism, with the regular advising arrangement complemented by Freshman Advisor Seminars, Residence-Based Advising, and the in-house advising provided by the Experimental Study Group.

In cooperation with the Office of the Dean for Undergraduate Education Office, we worked to encourage increased contact between freshmen, instructors, and advisors through a series of early performance alerts, in addition to the Freshman Watch and Performance Evaluation systems. Immediately after the first quizzes in Fall and Spring, recitation instructors met with students experiencing difficulty. Quick professorial feedback in many cases helped such students to avert further academic problems. A refined version of this system will continue during academic year 1991-92.

Freshman Advisor Seminars

This past Fall there were 66 Freshman Advisor Seminars, accommodating 540 of the 850 freshmen who applied for them; 20 academic departments were represented. For Fall, 1991, there will be a record 96 Freshman Advisor Seminars, representing 28 different academic departments and involving 94 faculty and nine administrative staff. We hope this year to be able for the first time in the program's six year history to accommodate all the freshmen wanting a Freshman Advisor Seminar.

Residence-Based Freshman Advising

This year the residence-based freshman advising program operated in eight living groups: three independent living groups (Alpha Delta Phi, Lambda Chi Alpha, and Sigma Alpha Epsilon) and five dormitories (Baker House, Bexley Hall, McCormick Hall, New House, and 500 Memorial Drive). There were a total of 27 faculty and administrative staff acting as advisors, 78 upperclass associate advisors, and 129 freshmen in the program. The same houses will be offering residence-based freshman advising next year.

A special augmented version of residence-based freshman advising was tried this year at Bexley Hall. The housemaster, Professor William Orme-Johnson, provided academic advising to the 24 freshmen in Bexley Hall. He was intensively assisted by 12 associate advisors, one for each two freshmen. In addition, 16 student tutors were hired to provide individual in-house tutoring to any student in the house who wanted or needed it. There were also weekly confidential discussion groups led by Bexley's graduate residents. Nearly all Bexley freshmen felt that all components of the program were very successful, and it will be offered again in the coming year.

Peer counseling also continued with the Big Sister/Little Sister program at McCormick Hall, the only all-women's dormitory, with upperclasswomen serving as "Big Sisters" to first-year "Little Sisters." The continuing goal for 1991-92 is to have all the freshmen in the dormitory assigned to a Big Sister, whether or not they are participating in the Residence-Based Freshman Advising program.

Committee on Academic Performance

CAP was chaired this year by Professor James L. Kirtley, Jr. The committee's work was complicated, particularly with regard to the freshman class, by the new definition of Pass as a grade of C level or better under Pass/No Record (P/NR) grading, a change which more than doubled the number of Warnings issued to first-year students. A concomitant lowering of the load limits for freshmen, to 54 units for Fall and 57 for Spring, brought increased pressure to exceed these limits by petition. CAP has evolved a policy which disallows all such petitions in the Fall, except in the most technically extraordinary cases, and which stipulates that Spring petitions will be granted only when accompanied by detailed supporting statements (from instructors as well as advisors) testifying to the student's unusually high level of ability and uniformly excellent record of performance in the Fall term.

CAP and UAS Actions on Freshmen Over the Past Five Years

Academic Year	Required Withdrawals	CAP Warnings	UAS Letters	Total Academic Actions
1990-91	15	223	80	318
1989-90	11	91	101	203
1988-89	14	107	82	203
1987-88	10	91	91	192
1986-87	8	91	84	183

In its dealings with the entire undergraduate student body, the Committee handled approximately 500 petitions requesting readmission and exceptions to certain regulations of the faculty. A total of 79 Required Withdrawals (1.8 percent of all undergraduates) and 469 Warnings (10.8 percent) were voted for the academic year, distributed by class as follows:

1990-91 CAP Actions on All Undergraduates

Class of	Required Withdrawals	CAP Warnings
1991	16	65
1992	20	74
1993	28	107
1994	15	223
TOTAL	79*	469

* In addition, 67 students withdrew and 34 took leaves of absence for a variety of non-academic reasons.

Residence/Orientation Week

This year's 12-day Residence/Orientation period was marked by the departure of our 14th President and the arrival of the 15th. President-elect Vest made his first public speech at the Institute during the Welcome Convocation for all new students, at which he joined President Gray and the President of the Undergraduate Association in welcoming the Class of 1994 to the MIT community. All three presidents emphasized the importance of the transition the students were about to make from their home communities to the diverse MIT community, which was depicted in an images-and-voices show. Following the Convocation, students broke into small groups where approximately 40 upperclass and staff facilitators sought, by means of games and frank discussion, to create a sense of the combination of openness and mutual respect necessary to the well-being of an ethnically and culturally diverse community.

A second theme of R/O '90 was design, embodied in a Design Project held the day after the new students arrived and in the choice of the Freshman Book. The Design Project began with a Kresge send-off by Professor Woodie Flowers, who spurred the Freshmen to a creative evaluation of design flaws on the MIT campus. This they accomplished armed with Polaroid cameras, poster board, pens and glue sticks in pre-assigned small groups; the resulting analyses were subsequently displayed in Lobby 7. The Design Project was reinforced by this year's Freshman Book, Donald Norman's The Design of Everyday Things, mailed over the summer to the entire entering class. Dr. Norman, an MIT alumnus and professor at the University of California, San Diego, appeared in Kresge on Book Night to amplify his theory of bad design. His talk was expanded upon by MIT's Sandra Howell, Michael Rosen and Jeremy Wolfe. Evidently the theme had general appeal, as faculty participation in Book Night dinner discussions reached an all-time high.

For the second year, the orientation workshop for New Faculty was combined with the workshop for New Graduate Teaching Staff. The combination proved successful and will likely be continued in future R/O's.

R/O Week was implemented by a Planning Committee consisting of upperclass students in collaboration with UASO and other ODSA staff. Executive Committee members were William J. Moliski '91, Beth L. Pruitt '91, and Brian F. Kelly '91.

Academic Counseling, Study Skills and Workshops

One of UAS's important activities is the involvement of staff in individual academic counseling. This kind of contact lies at the heart of the office's mission, reinforcing and supplementing the advisory work of assigned freshman and departmental advisors, and maintaining a highly visible resource where any student can get academic assistance promptly. During 1990-91 there were approximately 2,300 of these consultations, representing interaction with at least 1,500 MIT undergraduates.

UAS also offered a series of bi-weekly Study Skills Workshops in both the Fall and Spring semesters.

The Undergraduate Seminar Program

There were 51 Undergraduate Seminars for Fall term (including 20 "hybrid" seminars admitting both freshman advisees and other students and therefore counting also as FAS) and 29 in the Spring for a combined total of 85 for both semesters, with total undergraduate registration of about 1,000 students. There were also five House Seminars hosted by living groups this Spring.

This year there were several student-initiated seminars with a socio-political focus, such as "The Changing World of AIDS" organized by ARMIT (AIDS Response at MIT), "Gender Issues for MIT Women Students," "Nubian Notions for the 1990s," and "Topics in Asian American History."

This Spring a new special 12-unit undergraduate seminar entitled "Politics, Cambridge, and the MIT Student" was offered through the Political Science Department with the support of UAS, the Public Service Center, and the Context Initiative. This seminar was an attempt to integrate class discussion, reading, and writing with experiential learning in order to broaden students' understanding of the political, economic and social issues confronting the residents of the City of Cambridge. Seventeen students were placed in internships, either in direct service with residents of a local housing project or in policy-oriented placements with local political organizations or City Hall. One intern assisted the Cambridge Economic Opportunity Commission in the development of a food policy for Cambridge, which resulted in a well-orchestrated public hearing and a policy resolution by the City Council. Another intern assisted the Vice Mayor in the start-up of a new program providing educational enrichment to 20 third-grade African American males. Four students worked as school volunteers designing innovative programs for gifted inner-city students to teach chemistry and physics. The seminar was very successful in the eyes of both the students and the participating organizations, and it will be offered again next Spring.

Independent Activities Period (IAP)

IAP '91 was a transition year between the CUP-mandated experiments for IAP '89 and '90, and IAP '92, when departments will assume responsibility for academic offerings during IAP. Departments will plan their subjects a year in advance and submit them to the Committee on Curricula (COC) with all their regular subject offerings for the Spring and Fall terms. For IAP '91, the IAP Policy Committee continued to pursue the objectives outlined by the CUP for 1989 and 1990. These objectives included increasing student involvement (particularly freshmen), increasing the number of sustained and credit-bearing activities, and the development of more internship, public service and campus-wide programs. Substantial progress was made toward these goals in 1991, increasing IAP's success as a significant educational experience.

The number of *IAP Guide* activities offering credit has been steadily increasing from 28 in IAP '88 to 43 in IAP '89 to 51 in IAP '90 and 63 in IAP '91. During the same period, the number of undergraduate grades awarded for IAP has dramatically increased from 283 in 1988 to 393 in 1989 to 752 in 1990 and to 1,050 in 1991. In addition, undergraduates earned 829 physical education credits this past year, nearly two-thirds more than in 1988.

Many activities, especially those for credit, were frequently over-subscribed. Of 440 activities surveyed, 82 activities had limited enrollment. The total known number of students who were turned away from participating in an IAP activity was 890. Some 532 were turned away from 52 credit activities, 358 away from non-credit activities.

The number of sustained activities, that is, those meeting more than four times, increased significantly. The number of activities meeting four to nine times jumped from 76 to 100 activities, and those meeting more than 10 times nearly doubled from 20 to 39 activities.

Responsive to the CUP's mandate to increase and develop internships and public service programs, there were internships in Architecture and Political Science. Architecture internships increased from eight in 1989, to 17 in 1990, to 28 in 1991. Political science internships decreased slightly from 28 in 1990 to 26 in 1991. Students also became involved in "Gulf War" activities; students recruited Rev. Jesse Jackson to speak in Kresge Auditorium, which was filled to capacity. The speech was telecast to the Student Center to accommodate the overflow crowd. Students also founded and ran the Martin Luther King Jr. Peace Center in the Student Center, and sponsored several Gulf War teach-ins.

To improve contact between students and senior faculty and new administrators, UAS organized a series of luncheons entitled "Free Meal with a Big Wheel." The luncheon series, first of the Presidential Inaugural Celebration events, was held in January during IAP '91. The luncheon series matched five "Big Wheels" (President Vest, Provost Wrighton, Prof. Keyser, Prof. Jacoby, and Prof. Perkins) with a combined total of 127 undergraduate and graduate students over 10 luncheons.

In May, the IAP Policy Committee, chaired by Professor Linn Hobbs, gave a presentation to the Committee on Undergraduate Programs summarizing its conclusions and recommendations regarding IAP as follows: 1) IAP is a viable academic vehicle which adds a unique dimension to the education of undergraduates; 2) sustained and credit-bearing offerings are well subscribed and in many cases over-subscribed; 3) departments are generally cooperating with the IAP Policy Committee, discussing the utilization of IAP in curricula, and sorting out faculty staffing issues; and 4) the inclusion of credit-bearing activities does not pervert the original intention of an open learning experience. There are adequate safeguards for the compulsive student.

Wellesley-MIT Exchange

The Wellesley-MIT Exchange is a small program that offers interested students the opportunity to cross-register at an excellent liberal arts women's college and take advantage of its small classes, liberal arts curriculum, and rural setting.

In 1990-1991, 107 MIT students registered for 132 Wellesley courses as compared with 1989-1990, when 170 students registered for 200 courses. Four MIT students (one of whom completed a fifth year as a special student at Wellesley) earned their teacher certification through Wellesley's program. Three MIT students participated in the Residence Exchange.

The Wellesley-MIT Joint Committee was co-chaired this year by Professor June Matthews of MIT's Physics Department.

Improvement of Entry Process For Transfer Students

In response to complaints from transfer students about difficulties they encounter in making the transition to MIT, UAS convened a forum in the early Fall to enumerate and discuss these issues. During the following months a joint Undergraduate Academic Support/Residence and Campus Activities Offices' effort, under the leadership of the Dean for Student Affairs, has brought progress on several fronts: 1) The admissions and financial aid offers are made earlier; 2) Starting with the Fall 1991 entering cohort, transfers who want it are guaranteed on-campus housing for as many semesters as it will take them, at a normal rate of progress, to satisfy degree requirements; 3) A Pass/No Record grading option in all Science Requirement subjects, during the semester of entry only, is available to transfers who carry two or more such subjects; 4) UAS is unambiguously identified as the general support center for transfers during the transitional period as they adjust to MIT and establish secure departmental affiliations; 5) A new informational brochure, covering key matters of practical concern to transfers, will be mailed to them in July. One additional problem, the sluggishness of the transfer-credit process, needs to be addressed vigorously in the weeks ahead.

Staff

For the second consecutive year, UAS enjoyed entire staffing continuity, a happy state of affairs. In July, Moya Verzhbinsky will be leaving us to pursue graduate studies. Her contributions to UAS programs, particularly in the organization of R/O, and to the harmonious tone of the office's life, have been invaluable.

TRAVIS MERRITT
MARY ENTERLINE
DONNA FRIEDMAN
ALICE LAPIERRE

JEFFREY MELDMAN
STEPHEN PATTERSON
MOYA VERZHBINSKY
BONNIE WALTERS

STUDENT ASSISTANCE SERVICES

Student Assistance Services continues to operate as a point of contact for student concerns and the formal structures of MIT. Students may come here for a variety of reasons and the help they receive may range from immigration information to individual therapy. The goal is to help students move through the MIT experience in a healthy and hopeful manner.

1990-1991 was characterized by crisis and change. New staff support added to our ability to respond to demands in the international arena, and new faces filled three positions leaving the office fully staffed for the first time in nearly a year. The demands of the Gulf War cut across all areas of the office for not only did we have students with families caught up in the events in Kuwait, but we had students with siblings and parents fighting in Kuwait and Iraq. The challenge presented by the war was met well and illustrates the truth that the fine line between counseling and crisis management is exactly that - a fine line. By the end of the year the office had gathered the Host Family Program under its organizational wing and the program will be run from SAS in the new fiscal year.

Three important concerns developed during the year. They include the growing awareness of acquaintance rape as an issue on campus and the decision to begin programing during the coming year to respond to the issue. A second concern is the awareness that international crises can reshape the expectations of the office in a moment. After the upheaval in China began to wane we were faced with the events in Kuwait and then those in Yugoslavia, all of which demand sensitivity and awareness on our part as we respond both to the needs of students and the demands of the Immigration and Naturalization Service.

Finally, programing for minority students had waned in recent years, but this year it returned in several forms celebrating both the Black and Hispanic experience. Of special note was the very successful film series which involved the Native American, Black, Hispanic and Gay communities. Kwanzaa was a success in December and a slightly increased budget offers hope for the new year.

Important to note, but also painful was the role of the office in four student deaths during the fiscal year. Three are regarded to have been suicides and each placed special demands on the counselling services of the office. The year also

forced us to look carefully at the services we are offering to disabled students. The numbers are small, but they are growing and our resources are stretched thin both in terms of money and personnel.

This office interacts each year at a personal level with nearly a third of the student body. There is a need to make sure that our services are understood and utilized by even more students, but at the same time there is the recognition that what we do is done well. The spectrum is broad and ranges from support to students with special needs to programming for the minority communities to orientation for new international students to individual support in times of crisis and illness to support for/and training of the peer hotline, Nightline. For many we are the human face of MIT and that is a role not to be undervalued.

ROBERT M. RANDOLPH
DANIELLE GUICHARD-ASHBROOK
ARNOLD R. HENDERSON
DEBORAH L. HERMAN
MILENA L. LEVAK

AYIDA MTHEMBU
LYNN A. ROBERSON
JACQUELINE R. SIMONIS
BRIMA WURIE

RESIDENCE AND CAMPUS ACTIVITIES

The Residence and Campus Activities (RCA) section of the ODSA has responsibility for most aspects of the undergraduate dormitory system, the residents, Housemasters and Graduate Residents, house assignments, and student governance; graduate student government and some residential concerns; fraternities, sororities, and independent living groups; the Undergraduate Association student government; student activities and organizations; and discipline functions related to these areas. In addition, the section oversees some special programs, including the House Fellows Program and Talbot House.

The year's activity in each of the major RCA activities is summarized below.

Undergraduate Housing

Several factors, including a large incoming freshman class for the Fall of 1990, led to more undergraduates living in the Institute Houses than in recent years. Two hundred fourteen students were still living in crowded conditions by late September, compared to ninety-three last year, for a total undergraduate dormitory residency of 2,844. Forty of these lived in twenty lounges in the MacGregor House tower that were converted to doubles for the first time since 1985. By late February, the number of students living in crowded conditions overall was down to 144.

The vast majority of incoming students continue to be assigned to their first- or second- choice Houses, although assignments to some of the older Houses are more difficult. Improvements to the algorithm we use to resolve mid- and end-of-year switches and assignments gave us even greater latitude in granting requests for House-to-House switches and moves into the dormitory system. We are using these improvements as a starting point to investigate options for computerizing much of the lottery and assignment process.

Anticipating a change in policy that would guarantee housing to all undergraduate transfer students admitted for the Fall of 1991, we guaranteed housing to all Spring transfers as well as those denied housing in the Fall of 1990.

Housemasters and Graduate Residents

Dr. and Mrs. Kenneth Oye of the Political Science Department and Dean Ayida Mthembu of the Office of the Dean for Student Affairs brought new leadership to East Campus as Housemasters and Associate Housemasters respectively. Appointments for this coming year include Prof. and Mrs. Stephen Lippard of the Department of Chemistry as Housemasters of MacGregor House and Prof. and Mrs. William Porter of the Department of Architecture as Housemasters of Burton House. Leaving the system are Prof. and Mrs. Robert Kennedy, Department of Electrical Engineering and Computer Science, who served as Housemasters of MacGregor House since 1985, and Prof. and Mrs. Julian Beinart, Department of Architecture, who served as Housemasters of Burton House since 1977. Their contributions to the undergraduate residence system have been considerable and they will be missed.

In addition, 20 Graduate Residents left their positions in the Institute Houses at the end of this year and we welcome those selected as their successors.

As a follow-up to the Report of the MIT Committee on Sexual Harassment, a number of Housemasters and Graduate Residents embarked on noteworthy endeavors relating to sexual harassment. The Housemasters of Baker House and East

Campus developed, implemented, and analyzed a survey on harassment sent to all residents of those houses. Additionally, several workshops on sexual harassment, led by staff from both inside and outside MIT, were conducted for the residents in various living groups. These efforts were considered both successful and valuable by the Houses and will be built on in the following years.

With much combined effort from the residents, Housemasters, and Graduate Residents of Bexley Hall, the Coordinated Freshman Program for all incoming Bexley freshman was implemented this year. Combining residence based advising, tutoring, and weekly discussions, the House has deemed this program a success and has voted to continue it next year.

Fraternities/Sororities and Independent Living Groups

Fall 1990 rush results exceeded projections with 384 freshmen and transfers selecting a fraternity or independent living group as their residence for 1990-91. These numbers include 34 women, 29 transfers and 40 underrepresented minority students. An additional 84 women pledged one of the three non-residential sororities. A fourth sorority, Kappa Alpha Theta, was invited to colonize in February pledging 60 women in their initial effort and an addition 15 in their Spring rush.

Plans were completed and renovations begun on the new house acquired for Alpha Phi Sorority. The property, located at 477-479 Commonwealth Avenue, Boston, will house 60 female students and a house director and be ready for occupancy August, 1991.

The Alumni Interfraternity Conference Insurance Program improved its coverage for its member living groups and lowered its rates at the same time. An additional fraternity joined the program this year while one left. Independent Residence Development Fund (IRDF) funded renovations were completed at two locations and several more are in the planning stages for 1991-92. A successful liability and risk management workshop for house corporation and undergraduate officers was sponsored by RCA in March.

An inspection of life safety systems of the 33 Independent Living Group facilities was conducted in the Spring. The survey was jointly funded by ODSA and the Office of the Senior Vice President. The information gained will be used to establish minimum safety standards for ILGs to qualify as "MIT Approved Housing".

The Mu Tau Chapter of Alpha Epsilon Pi (AEPi) Fraternity grew to 13 members after it was reorganized by AEPi National the previous year. At the request of its alumni and current undergraduates, ODSA granted the chapter "Approved Housing" status for entering freshmen. The Interfraternity Council, however, refused to grant AEPi membership in its organization.

Two fraternities, Sigma Alpha Epsilon and Phi Gamma Delta, were placed on disciplinary probation by the Dean's Office for serious incidents of misconduct involving members of their organizations.

Several MIT fraternity chapters including Beta Theta Pi, Delta Tau Delta, Phi Delta Theta, Sigma Chi and Sigma Phi Epsilon were recognized as among the most outstanding in North America by their respective national organizations.

House Fellows Program

This past year marked the fourth year of the House Fellows Program, which was established in 1987 to promote greater interaction and sense of community between students in Institute Houses and MIT faculty members. The program this year involved 22 House Fellows in three undergraduate and two graduate dormitories and eight independent living groups. Efforts this year will be directed towards recruiting MIT faculty members to participate as Fellows and matching them with interested living groups.

Campus Activities

With the recognition of a wide variety of groups this year, the Campus Activities program of over 200 organizations remains strong. The Campus Activities Office, Association of Student Activities and the Undergraduate Association all modified policies and procedures in order to better monitor and serve student groups.

Under the leadership of Kate Mahoney, the Association of Student Activities' September midway drew an even greater level of participation from both new students and group organizers. The ASA also tackled the problem of unsightly "poster pollution" by amending its poster policy.

The Undergraduate Association, headed by President Manish Bapna, achieved numerous successes this year. Among these were the restructuring of the UA Council, an increased attention to providing tangible services to students, such as shuttle bus service and a jointly sponsored student/faculty seminar series.

In collaboration with the UA sponsored Alcohol Policy Committee, the Campus Activities Office participated in the review and rewriting of the policies and procedures for campus events where alcohol is served. In addition, the Campus Activities Office and the Health Education Office sponsored a "Social Midway" which provided students with programming alternatives and suggestions for alcohol-free social events. The Campus Activities Office continued to provide outreach to student groups and leaders on topics as varied as party management, effective meetings and publicity campaigns, and leadership development.

Finance Board for Undergraduate Association and Student Activities

Student Activity Accounts have experienced another year of increased activity. Income activity for the year totalled \$514,775 compared to FY '90 income activity of \$228,857, an increase of approximately 125 percent. Much of this increased activity reflects the result of more groups holding accounts in the Undergraduate Association office and of some groups dissolving outside bank accounts in order to keep all of their funds in their MIT held account. This office has been working for the past few years to encourage all student activities to use internal MIT accounts. To date, the results of our efforts in this area have been gratifying.

In order to deal with the increase in activity and money flow, student help has been arranged to help with the paperwork process. Also, a new software recording system utilizing a relational database has been developed for our updated and more powerful Macintosh in order to better track individual groups and the overall UA accounting process. This program has just been completed and will be in operation during the current fiscal year.

In order to have other areas of MIT work more successfully with student activity accounts, a TechInfo bulletin board has been created and will be continuously updated with financial information about MIT's student activities.

Discipline and Harassment

This year the RCA staff heard more than 80 disciplinary cases, including 34 involving harassment. The number of cases is about the same as last year, though there has been an increase in the number of harassment concerns brought to this office, possibly as a result of the increased awareness of this issue brought to this campus by the Report of the MIT Committee on Sexual Harassment issued in October 1990. Charges in these cases included rape, death threats, arson, harassment, distribution of a controlled substance, assault and battery, grand theft, violation of freedom of speech, destruction of property, alcohol and drug abuse, and trespass. The sanctions imposed ranged from verbal warnings to recommendations of expulsion and suspension to the President, declaration of Persona Non Grata status, removal from MIT housing, community service, reimbursement for damages, and probation.

Talbot House

During the 1990-91 school year, 66 groups visited the House, a slight increase over the 64 groups of 1989-90 and the 61 groups of 88-89. The House was in use 134 out of 365 nights and 42 out of 52 weekends.

The major news in House operations is the failure of the original septic tank. MIT has been working with the State of Vermont and Laurance Rockefeller's (who donated Talbot House to MIT) organization in Woodstock to find a suitable site for a new (larger) tank. Due to the change in environmental requirements since the original tank had been installed, its present location next to a stream is not acceptable to the state, especially as it handles the wastewater from as many as 27 people.

The exterior of the House was painted this summer, new shingle roofs were put on the two front porches and minor repairs to the clapboards were made.

Staff Changes

This year we welcomed Eliot Levitt to the RCA Staff. Eliot was initially hired for the part-time position of Senior Office Assistant in support of undergraduate housing and the independent living groups and then in January hired for the position of Staff Assistant for Residence Programs, after John Keefe left the office. As a result of that change, Christine

Simmons, formerly Senior Office Assistant for the Undergraduate Association, became the part-time Senior Office Assistant for undergraduate housing and the independent living groups.

JAMES R. TEWHEY
NEAL H. DOROW
ANDREW M. EISENMANN
STEPHANIE HARRISTON-DIGGS

SUSANNA C. HINDS
ELIOT S. LEVITT
SHARON P. SHEA

THE OFFICE OF MINORITY EDUCATION

In the 1990-91 period the Office of Minority Education (OME), made continued strides and met new challenges to reassess and strengthen existing academic programs, develop effective means of communication and cooperation with other MIT offices, and reinvigorate our quest for excellence in the delivery of educational services to underrepresented minority and other students.

Highlights of major accomplishments and special events are described below.

Project Interphase (PI) '90 enrolled 51 African American, Mexican American, Native American, and Puerto Rican students from 18 states and Mexico. Nineteen (37 percent) of them were female. The 1990 curriculum included physics, math, writing, and physical education. A weekly study skills component provided additional academic support. A site visit to Digital Equipment Corporation in Hudson, Massachusetts, added a new element to the academic enhancement components of this 8-week summer residential program for entering students.

The small-group learning concept was used in both the physics and the math components in PI '90. These, as well as the writing component, each carried four units of credit. Successful completion of the writing component satisfied Phase I of the MIT writing requirement. Students also satisfied the MIT swimming requirement through successful participation in the PI physical education component. Of the 51 participants, 20 (39 percent) achieved sufficient mastery of first-level calculus to place out of 18.01 for the Fall '90 term.

The PI '90 survey conducted by Alberta Lipson, Assistant Dean for Research, indicated strong overall participant satisfaction by 92 percent of the 51 students enrolled, with similar consensus on the part of the PI faculty and staff.

Program XL, a now two-year-old academic initiative in minority education at MIT, is designed wholly on the small-group learning concept. It is an academic enrichment program focusing on calculus and physics for first-year students. Study groups of five or six participants meet with facilitators trained in concept focus and classroom techniques. They work on analytical skills and test-taking strategies to enhance students' performance in calculus and physics. A group of 6.001, the computer science programming structure course, was added in the Spring '91 term.

The 1990-91 academic year saw continued success of Program XL. Twenty-seven students enrolled in XL calculus groups for credit in the Fall term. Of that number, 23 passed their calculus with a grade of C or better. Of the four students who received no credit, one received an F. Thirty students enrolled in XL physics for credit in the Fall term. Of that number, 25 passed with a grade of C or better. None received an F.

Characteristically, Spring enrollment in XL is smaller than in the Fall. Eighteen students enrolled in XL for credit in the Spring '91 term. All of them passed both physics and calculus with a grade of C or better. Of the six students in the 6.001 group, one received a D (thus, no credit) for the course, two dropped the course early in the term, the others received a grade of C or better.

Use of the **OME/BSU Tutorial Program (TP)** increased from the previous year. There were a total of 225 visits from students for tutoring in 29 different subjects in Courses I, II, III, V, VI, VII, VIII, X, XVI, and XVIII. There were slightly more tutoring requests from sophomores (34 percent) than from freshmen (25 percent). This was due in part to the implementation of Program XL, which enrolls only freshmen. Juniors accounted for 21 percent of the requests for tutoring, and seniors accounted for 18 percent. Indications from the 1990-91 academic year are that increased participation by graduate tutors must be achieved in order for the OME to more effectively meet the tutoring requests from upperclass students. A small number of graduate students (2 percent) also made requests for tutorial services.

The OME took measures to both address the need for increased graduate student tutoring as well as to achieve direct faculty participation in the planning, delivery, and evaluation of OME tutorial services. The position of Academic Officer was created for the Tutorial Program toward the end of the 1990-91 academic year, and Professor Jerome Friedman will be the first faculty member to serve in that capacity, beginning with the 1991-92 year.

Secrets and Strategies for Academic Success was successfully coordinated with the help of student assistants. Monthly sessions were held dealing with choosing a major, writing resumes and preparing for interviews, and negotiating the corporate culture. Corporate presenters from Digital Equipment and Hewlett-Packard assisted in the latter sessions; MIT resource individuals from the Undergraduate Academic Support Office and the Office of Career Services and Preprofessional Advising assisted with choosing a major as well with resume writing.

The **Buddy Program** enjoyed a very successful year. Some 45 upperclass students served as buddy to more than 55 freshmen and a few sophomores who requested the service. The OME facilitated the development of relationship building between buddy and freshman through sponsorship of small-group activities, as well as initial and end-of-term events in plenary sessions.

New Initiatives and Major Activities

The establishment of an Industrial Advisory Council for Minority Education (IACME) added both excitement and many possibilities to OME programs, and promises to be a major force in the implementation of academic support and enhancement efforts for many years in the future. With representation from 19 Fortune 500 companies, the IACME was welcomed by President Charles M. Vest at the first meeting in October 1990. A second scheduled meeting was held in February 1991, and the third in May 1991, involving their attendance at the annual Minority Awards Banquet. As one of the initiatives mounted through the IACME, a mentor program was developed for implementation in the 1991-92 academic year. Engineer and scientist volunteers were identified by the companies to be paired with MIT students participating in OME programs.

OME was joined by the Offices of Special Assistant to the President, Graduate School, Career Services, and Student Assistance Services to sponsor the 15th annual **Minority Awards Banquet**. Some 84 underrepresented minority students were recognized for academic achievement having attained a cumulative grade point average of 4.2 or better. Awards were given for various service categories and leadership activities and achievements, including awards to graduate students by the Graduate School Office. Honors were accorded to artists from the community who assisted MIT students in special events and activities during the year.

The second annual **Hispanic Week** celebration was coordinated by student assistants, with help and support from the Office of Student Assistance Services.

Other activities supported or co-sponsored by the OME included a celebration of:

Kwanzaa	Minority Spring Weekend
Black History Month	Martin Luther King, Jr. Day
Implementation of the first Martin Luther King, Jr. Visiting Scholar Program	
Buffet Luncheon for Graduating Students of Color and Their Families	

The newly formatted, OME newsletter, with unique logo designed by MIT minority students, enjoyed continued circulation. ***SPIRIT: the OME Newsletter*** reached the hands of a readership that included some 600 students, faculty, administrative staff, alumni officers, and students' families.

Student Organizations and Committee Involvement

The Office was able to continue traditional support and add a new dimension of support to these student organizations:

- American Indian Science and Engineering Society (AISES)
- Association of Puerto Rican Students (APR)
- Black Students Union (BSU)
- National Society of Black Engineers (NSBE)
- Native American Students Association (NASA)
- Society of Hispanic Professional Engineers (SHPE)
- La Union Chicana por Atzlan (LUChA)

The OME continued to benefit from the very valuable support and insight of the OME Faculty Advisory Committee.

Staff Changes and Personnel Development

A national search was conducted to fill the position of Assistant Director of OME, vacated in January 1991. The search yielded more than 85 formal applications from 23 states. Approximately one half of the applicants for the position were women. The process resulted in the selection of an Assistant Director who will begin his service in late August 1991.

**FALL 1990 ENROLLMENT STATISTICS FOR UNDERREPRESENTED MINORITY
UNDERGRADUATES**

Total Undergraduates All Groups: 4,389	African American	Native American	Mexican American	Puerto Rican	Totals
Group Total	290	23	190	85	578
% Min. Enroll.	50	4	32	14	100
% Total Enroll.	6.6	0.5	4.3	2.0	13.4

JUDY J. PITTS
ALBERTA LIPSON
GAIL-LENORA STATON

Facilities Use Committee

Reporting to the Associate Provost for Educational Policy and Programs, the Facilities Use Committee formulates and implements policy for the use of Institute facilities by recognized MIT groups, guests from off-campus, and by non-MIT organizations hosted by Faculty and recognized campus groups.

Chaired by Stephen Immerman, Director of Special Services, Office of the Senior Vice President, this year's committee membership included Roderick Arthur, Assistant Athletic Director; Robert Cunkelman, Staff Mechanical Engineer, Physical Plant; Gayle Fitzgerald, Manager of Conference Services; Winston "Pat" Flynn, Associate Registrar, Facilities and Scheduling; Michael Foley, Manager, Campus Activities Complex; Brenda Generazio, Senior Staff Assistant, Office of Government and Community Relations; Susanna Hinds, Director of Campus Activities; Mary Morrissey, Director of the Information Center and Special Events; Patricia Murphy, Administrative Assistant, Campus Activities Complex; Paul Paravano, Assistant for Community Relations; and Phil Walsh, Director, Campus Activities Complex.

During the 1990-91 year, in addition to a number of smaller meetings, the Institute hosted a symposium sponsored by the Chemical Engineering Department celebrating the 75th Anniversary of the founding of the School of Chemical Engineering Practice, Bone Marrow Testing by the American Red Cross, the Whitehead Institute Symposium, the Mind/Body Institute Symposium, the National Science Foundation Conference, a concert by the Morehouse College Glee Club, the Massachusetts State Science Fair, the Bay State Games, a conference of the Navel Research Laboratory, a meeting of the AIAA Space-Based Observation Committee on Standards, an educational forum on computers for elementary school children jointly sponsored by Information Systems and the Boston Computer Society, the Boston Latin High School Commencement Awards Ceremony, and the Boston Tech High School Commencement.

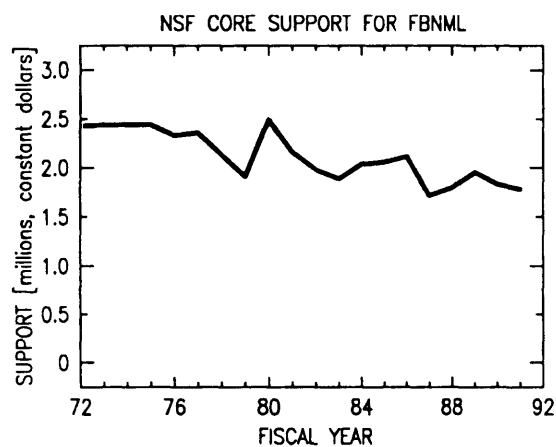
Stephen D. Immerman

Associate Provost and Vice President for Research

Francis Bitter National Magnet Laboratory

The Francis Bitter National Magnet Laboratory (FBNML) was established in 1960, with support from the US Air Force, as the first high magnetic field laboratory in the country. It continues to be the primary facility for high magnetic field research in the US, and operates high magnetic field facilities available, free of charge, to qualified scientists throughout the country. The Laboratory can produce a world record 31.8 tesla (T) in a 33 mm bore, and pulsed fields up to 68 T of duration >5 ms are available on an experimental basis. A 36 T magnet will become operational in the fall of 1991. The Laboratory also designs and builds magnets, both

resistive and superconducting, and performs in-house research in condensed matter physics, condensed matter chemistry, materials science, and biophysics.



Responsibility to support the Laboratory's operations was assumed by the National Science Foundation (NSF) in 1971. The figure at the left shows the NSF core support provided for FBNML operations since then. The data have been corrected for inflation using the published consumer price index. (It is widely accepted that the CPI underestimates the inflation rate for scientific research by a factor between 1.5 and 2.) A first look at the resource needs of national facilities was provided by a National Research Council committee on major materials facilities, chaired by Frederick Seitz and Dean Eastman, which issued its

report Major Facilities for Materials Research and Related Disciplines in 1985. In 1987, the NSF appointed a panel of eminent scientists, chaired by Robert Richardson and Frederick Seitz, to give specific advice on the future course of US high magnetic field research. In its 1988 Report of NSF Panel on Large Magnetic Fields, the panel identified many important scientific and technical opportunities in high magnetic field research and recommended the establishment of a National High Magnetic Field Laboratory (NHMFL). The NSF solicited proposals to establish the NHMFL in late 1989, and MIT submitted a proposal on May 1, 1990, to establish a NHMFL based upon the FBNML. Three proposals were received, the others being from the University of New Mexico and a consortium of Florida State University (FSU) and Los Alamos National Laboratory (LANL).

The proposals were evaluated by three stages of peer review. The first stage was a written mail review by ten experts who read all three proposals. Nine of the ten recommended choosing the MIT proposal. The second stage was a report by a panel of eight experts who visited the sites of all three proposals; this panel unanimously recommended the MIT proposal. The third stage of peer review was provided by the Materials Research Advisory Committee of the NSF Division of Materials Research, which found the MIT proposal to be technically superlative and voted eleven to one to establish the NHMFL at MIT. In August 1990, the NSF staff recommended to the National Science Board that the NHMFL be established at FSU. Subsequently, the Board approved this recommendation by a vote of nine to one.

As FSU and LANL had no expertise or experience in high magnetic field research or the design, construction, and operation of high-field magnets, the decision worried the scientific community. Practitioners of high magnetic field research were concerned that they would fall behind at a time when competing magnet laboratories in Europe and Japan were involved in major upgrades of their facilities. They felt that the NSF plan to send them to do their research at the Institut Laue Langevin in Grenoble was impractical. The US is now marginally ahead in the technology of high magnetic field research, and many were concerned that the NSF decision, combined with the FSU intention to obtain its magnets from Grenoble and Oxford Instruments, would condemn the US to a second-class position for the foreseeable future.

Subsequently, the NSF developed a plan for the next five years which involved keeping the FBNML operational at least through 1993. In response to this plan, the FBNML submitted a proposal requesting funds to operate the Laboratory for four more years, through the end of fiscal year 1995. This was done because the

Laboratory has always placed service to the user community as its top priority, and wished to continue operating the high field user facility until such time as better facilities were available elsewhere. Even if the most optimistic plans for the NHMFL were realized, the facilities it would be able to provide to dc high-field users after five years will not match those currently available at FBNML. Therefore we thought it necessary to continue the operations of the high-field facilities at least until the fall of 1994.

The magnet technology division of the FBNML is the best in the world for high-field magnet development, and is a national resource which it would be tragic to disband. Therefore, we also sought NSF support to preserve this group of talented people. We proposed completing our current magnet development projects, to press forward with very high field, high-resolution NMR, and to design and produce the next generation hybrid magnet. These are goals which the FBNML was uniquely qualified to pursue and which the Seitz-Richardson panel found especially promising.

At this writing, it appears that the NSF will provide the funds to operate the FBNML high field facility through fiscal 1995, and will also fund an engineering research project to design and construct the world's most powerful dc magnet, designed to produce a field of 45 tesla. This magnet project will be in cooperation with NHMFL staff and the magnet will eventually be installed in the NHMFL in Tallahassee. The total NSF support for this activity is expected to be \$23,000,000 over four years, and the NHMFL will provide an additional \$4,000,000. This arrangement will provide the best possible support for high magnetic field research in the nation, and stabilizes the situation at the FBNML while the future of the laboratory is decided.

J. DAVID LITSTER

Center for Cognitive Science

Introduction

The academic year 1990-91 continues to be a year of consolidation and retrenchment for the Center for Cognitive Science. The original Sloan Foundation Grant was awarded to the Center in 1979. That grant sustained Center activities for a decade. Now that those funds are almost exhausted the Center Working Group has decided to reduce spending considerably so that the most important Center activities can continue into the future.

Computational Laboratory

The primary target for retrenchment is the Computational Laboratory. There are two concentrations of equipment, one in Building 20, primarily serving Center members from the Department of Linguistics and Philosophy (L&P) and visitors to the Center, the other in Building E10, primarily serving members from the Department of Brain and Cognitive Sciences (BCS). The facility in 20C-231 contains a Microvax III running DEC ULTRIX, which is used to train graduate students in LISP-based simulations of human sentence parsing, to maintain the on-line dictionaries created by the Lexicon Project, to format and laser-print technical manuscripts in linguistics and logic, to simulate human reasoning, and for electronic mail.

In 1989-90 the facility in Building E10 was removed from the financial and administrative jurisdiction of the Center and transferred to BCS. There are plans to merge it with the Whitaker College Computing Facility, so that it can be more easily supported by grant funds from faculty members and graduate program grants from within BCS. This has become necessary now that the funding of the Center is running low and two facilities can no longer be supported by it.

The Building 20 facility, in transition last year, has now been replaced by Project Athena resources. The replacement was supervised by Professors Sylvain Bromberger, Ned Block, and David Pesetsky, who have taken over from Professor Steven Pinker the responsibility for overseeing the Building 20 facility, and they will continue to oversee the operation of the Project Athena connection.

Funding saved by these switch-overs has been used for research activities, the most notable of which is the Center Colloquium.

Research

The Parsing Project

During the past year, the Parsing Project continued its seminar series of invited speakers as well as research into principle based parsers. This work continues in the Center.

The Lexicon Project

The Lexicon Project focussed attention primarily on theoretical matters relating to lexical theory and a number of working papers were produced by the project's principal investigators. In addition, a working model of an electronic dictionary constructed in accordance with theoretical principles was produced. This pilot project proved successful and indicates the feasibility of a practical device.

Programs for Visitors

The Affiliate Program

The Center continued its affiliate program, which provides formal status for individuals who are connected with Center research but are not in residence at MIT. Affiliates are individuals who are working actively in the field and observers of the field who wish to have an affiliation with the Center.

The Member Program

The Center maintained its Member program, which provides individuals within the MIT community with formal affiliation. The program was designed for individuals whose interests significantly overlap with and support the intellectual goals of the Center. At present there are seven designated Members of the Center: Professor Kenneth Hale of L&P, Professors Emilio Bizzi, Whitman Richards, and Jeremy Wolfe of BCS, Professor Suzanne Flynn of Foreign Languages and Literature, Dr. Stefanie Shattuck-Hufnagel of the Research Laboratory of Electronics, and Dr. Lucia Vaina of Health Sciences.

papers on a variety of topics relevant to the Center. The papers are distributed to seminar participants before the meeting. At the seminar itself, a commentator or commentators present the paper. The author follows with comments and the paper is then open for general discussion from the floor. During the past decade a number of seminal papers in cognitive science received their first public airing in this forum, which has attracted an audience from all over the Northeast. Last year, in particular, over 400 members of the community attended a total of 6 seminars. Second, the Lexicon Project continued its fortnightly meetings on topics about the structure of the lexicon. These meetings were attended by approximately 200 scholars from a number of MIT departments and other institutions in the area. Third, the Center initiated the Parsing Project seminar, attended on a fortnightly basis by scholars from MIT and other institutions.

Publication Programs

The Occasional Paper Program

The Center for Cognitive Science sponsors a series of Occasional Papers. The papers are designed to inform fellow workers in the field of the current research undertaken at the Center. To date approximately 47 Occasional Papers have been published, a number of which are authored by visitors to the Center and represent work accomplished during their stay.

The Lexicon Project Working Papers

Lexicon Project Working Papers are sponsored by the Center. These papers describe the work carried out at the Center in conjunction with the Lexicon Project. The aim of these papers is to report current research on the Lexicon Project. To date, 40 papers have been published.

The Parsing Project Working Papers

The Parsing Project has begun its own working paper series. To date, six collections of papers have been published.

Other Publications

The Center for Cognitive Science has supported a variety of publications by making its resources available to visiting scientists and affiliated faculty. As of the end of the academic year 1989-90, a total of more than 20 books and over 200 articles have been published in part with Center support.

SYLVAIN BROMBERGER
SAMUEL JAY KEYSER
STEVEN PINKER
Co-Directors

Center for Materials Science and Engineering

Much of the technology that is essential to our national economic and social well-being is founded upon (and, not infrequently, limited by) the availability of materials with properties and performance adequate to their intended application. Conversely, the discovery of a new property or the development of a new class of materials will often generate new industries. An understanding of the relationship between composition, structure, and properties of materials is accordingly essential to future technological development. At the same time, the science and engineering of condensed matter continue to provide stimulating intellectual challenges. Unanticipated discoveries have caused excitement throughout the materials community, as well as capturing the imagination of the press. Quasicrystals, oxide superconductors, and the properties of atomic-scale clusters ("quantum dots") or nanoscale structures ("quantum wires") constitute but a few examples. The nature of these problems is such that an interdisciplinary approach is required if significant progress is to be made.

Similar feelings, in advance of their time, led the Advanced Research Projects Agency (ARPA) to establish the Center for Materials Science and Engineering (CMSE) in 1960 as one of a system of Interdisciplinary Laboratories (IDL's) at selected research universities. Support for these laboratories was assumed by the National Science Foundation (NSF) in July 1972 under the Materials Research Laboratory (MRL) Program of the National Science Foundation's Division of Materials Research. The central concept in the MRL Program remains the conviction that progress in many significant materials problems will be achieved only if interdisciplinary collaborations can be fostered that combine the viewpoints and backgrounds of a broad set of traditional departments of science and engineering. The MRL Program, accordingly, has three components. They are provision of funding for coordinated multi-investigator projects in what are termed "major thrust areas;" provision of "seed funding" for support of junior faculty or established faculty who are initiating work of relevance to an area of thrust; and, thirdly, the establishment, maintenance and operation of major central research facilities. A unique feature of the MRL Program is the significant local autonomy that is delegated to participating laboratories for the planning and management of their programs. The MRL's are thus able to utilize effectively faculty and institutional resources and can act quickly on new research opportunities. These principles and philosophy continue to be the basis upon which NSF commits substantial core funding for the Materials Research Laboratories. This core funding continues to represent virtually the entire source of support for CMSE. The funding allocated to the MRL Program at NSF has been stable for several years, but has either remained constant or grown at a subinflationary rate as other newly-created materials programs that are block-funded compete for available resources. The funding level of the individual MRL's has mirrored the overall MRL budget. Budgetary limitations have been exacerbated in the period of the present report and represent the primary constraint on the operation of programs in emerging areas that we view as important. Two developments during the past year portend a still more lively competition. First, after internal review at NSF, it was felt that the nine current MRL's appeared to constitute a "closed club." (No new MRL, indeed, had been established for more than a decade.) NSF issued a program solicitation with a deadline of September 1991 for the establishment of at least one new MRL in FY1992. Secondly, it was announced that requests for renewed support for existing MRL's will compete with proposals to establish new MRL's.

As is the case with awards made to many individual investigators by NSF, the MRL grant that supports the activities of the center has a three-year cycle, at the end of which a renewal proposal is prepared. This is followed by peer review in the form of both comments solicited by mail, as well as a site visit. Our proposal for a three-year renewal was submitted to NSF on August 1, 1990. The proposal requested funding for modified continuations of research in four areas-of-thrust and for a fifth new initiative. The support requested for the first year represented an 18.5 percent increase in funding above the level awarded for the 1990-91 program year, largely reflecting the addition of investigators for the proposed new initiative. A site visit by representatives of three national laboratories, five universities, and one industrial laboratory, augmented by three members of the NSF staff, took place November 13-15. The site visit seemed to go smashingly well. Funding was recommended for all four continuing areas-of-thrust, as well as for the fifth new initiative. Specific investigators, however, were identified as being less strongly integrated in the research teams than others and were not recommended for continued support. Such reductions, if implemented in the recommended form, would have (probably not by coincidence) reduced the operating budget for the first year of the program to the level of that of the preceding year. In a form of double jeopardy, however, damaging mail reviews were received after the site visit report had been submitted, which led NSF management to decline recommendation of one

continuing thrust for renewal. (This portion of the CMSE research program is to be brought to conclusion by February, 1992.) The final operating budget for the first year of the three-year continuation commencing March 1, 1991 was therefore 7.0 percent less than the budget for the 1990-91 program year. The scope of the programs and activities of CMSE during the past year thus divide into periods prior and subsequent to the start of our new program cycle on March 1, 1991.

CMSE supported research in four areas-of-thrust through March 1, 1991. The research ranged from examination of the mechanical behavior of intermetallic compounds that have realistic potential for engineering application in gas turbine engines to the fundamental science of phase transitions or the mechanism of superconductivity in oxides. A new initiative on the structure and properties of interfaces in ceramic oxides began in March. Highlights from each of these five thrust areas, along with the names and departmental affiliations of the principal investigators, is provided in subsequent sections. More detailed descriptions of the individual projects may be found in *Research in Materials, Annual Report*, compiled, published, and distributed by CMSE on behalf of the broader materials community at MIT.

Fifteen seed projects were funded in the 1990-91 program year. Principal investigators were faculty drawn from five academic departments. The great majority (9 of 13) were awarded to junior members or newly-appointed members of the faculty. A majority (7 of 13) represented research that was closely related to an established area-of-thrust and five investigators have, indeed, been incorporated into thrust area teams, as of March, 1991. Altogether, CMSE supported thrust area and seed projects for 42 principal investigators in seven different academic departments, on the order of one-third of the departments that exist at MIT. We estimate that approximately 20-25 percent of the materials research performed at MIT is directly supported by CMSE through NSF/MRL funding. CMSE provides significant indirect support, however, through operation of its central research facilities. During 1990-91, on the order of two-thirds of the activity in these laboratories was associated with non-MRL research. A subsequent section highlights the addition of apparatus and expansion of capability of these facilities.

The hands-on "open shop" basis on which these central facilities are operated, as well as the interdisciplinary flavor of the research that is conducted within CMSE, provides a rich setting for the training of undergraduate and graduate students. In 1990-91, CMSE provided financial support for 28 semesters of UROP activity for 23 students registered in six different academic departments. About 60% of all principal investigators for both thrust area research and seed projects supervised a UROP project at some time during the three-year period of our preceding program. Student interest was fairly uniformly distributed among the seed projects and thrust area research. The research on superconducting oxides was the sole outstanding exception. Wide publicity and the rapid pace of developments in this field caused undergraduates to be excited about an opportunity to participate in and to contribute to these discoveries. Not surprisingly, therefore, the participation of undergraduates in this area of thrust was twice that represented by our other activities. About one-third of the participating UROP students conducted their research under the supervision of a faculty member affiliated with a department other than their own. This indication that students are following their interests across traditional departmental boundaries provides, we believe, additional evidence of the ability of CMSE to provide a focus for interdisciplinary training.

In addition to serving as principal investigators of thrust area and seed projects, faculty participate in the operations of CMSE in two major administrative capacities. Requests for capital equipment, the review and renewal of seed proposals, space changes, and overall CMSE policy are made after discussion and recommendations made by an Internal Advisory Committee. Faculty who are leaders of the thrust area research programs serve as members of this group. Additional faculty members are selected as members-at-large to insure broad representation of the academic departments that participate in CMSE programs, as well as representation from key central facilities. Professors Samuel Allen, Ali Argon, and Mark Wrighton left the committee in March 1991, each after several years of valued service. Professors Mehran Kardar and Michael Rubner accepted appointments to the committee at that time, joining continuing members Robert Cohen, Carl Garland, Marc Kastner, Robert Silbey, and John Vander Sande. In addition to faculty who serve on the Internal Advisory Committee, other faculty participate in the supervision and operation of the central facilities. Each laboratory, in addition to one or more research specialists who serve as laboratory supervisors, is also overseen by a faculty advisor, who provides technical guidance, as well as advising CMSE on needs, trends, and new developments in the instrumentation provided by that particular facility. The instruments and capabilities of the CMSE central facilities are described in the *Central Facilities Directory*, a booklet that is updated every

one to two years and distributed to MIT faculty with interests in materials research, as well as to outside users at sister institutions and in industry.

CMSE attempts to serve as an interdepartmental focal point for materials research for a broad community at MIT. Among the ways in which CMSE functions in this role by assumption of the responsibility for coordinating, assembling, and publishing interdepartmental reports. These include *Research in Materials* (over 440 pages in 1991) and *Polymer Research Annual Report* (125 pages). These publications provide focus and showcase of the full range of materials research conducted at MIT and are widely distributed by CMSE without charge. The center, primarily through its central facilities, presented a number of minicourses and IAP programs during 1990-91. The majority of these programs were designed to introduce students to the capabilities and operation of the instruments in the central facilities. CMSE operates a weekly colloquium series that is traditionally held at noon on Fridays. During the spring semester of 1991, CMSE continued for a second year a successful experiment in which the colloquium focused on presentations by members of one of the thrust area research teams supported by MRL funding. The spring colloquium series of 1991 was based on the research on structured fluids that is conducted within the Phases and Phase Transitions Thrust. The funding that would ordinarily have been used to provide travel expenses to permit a series of visiting speakers to be present for but a brief period prior to and after their lectures, was combined to permit an outstanding researcher to be in residence on campus for a more extended and relaxed period of interaction with students and faculty. The individual designated as the Second CMSE Distinguished Visiting Scholar, on recommendation of members of the thrust, was Dr. Jacques Villain of the Centre d'Etude Nucléaire de Grenoble, France. Dr. Villain, who has made seminal contributions to the theory of phase transitions, was in residence during the week of April 22-26 and presented a series of three lectures that highlighted the theory of two-dimensional phase transitions. CMSE attempts to serve as an interdepartmental meeting ground for students and faculty whose work involves materials in yet other ways. The center operated, beginning with its inception, a reading room whose name honored Professor Arthur von Hippel, a long-time member of the MIT faculty and director of the Laboratory for Insulation Research, whose "molecular engineering" was an important antecedent to the present-day concept of a materials science. Use of the reading room had declined significantly over recent years after funding constraints required the libraries to discontinue support for a librarian to maintain and oversee the collection. Similarly, CMSE was forced to reduce greatly and eventually curtail subscriptions to the key journals secured for the room, largely as a consequence of their rapidly escalating cost. In order to have this space better serve the MIT community, the reading materials were returned to the MIT library system. The room was refurbished and equipped as a meeting room able to accommodate up to 55 people for a seminar, meeting, or thesis presentation. The general availability of the room will be announced to the MIT community in September 1991 at the start of the fall semester, pending the final installation of projection equipment. News of the room's existence has spread and it has already seen appreciable use during the spring of 1991. The facility will continue to be known as the von Hippel Room to continue the honor intended by the original designation.

PERSONNEL CHANGES

Personnel at the center fall into two categories: a director and administrative staff in CMSE headquarters and a technical staff that is relatively small, as most CMSE research is conducted by students and faculty associated with individual academic departments. CMSE technical staff consist predominantly of research specialists charged with maintenance of the apparatus in the CMSE central facilities and instruction of users in their operation. The present administrative staff remained unchanged during the third year of its tenure in 1990-91.

Personnel changes during 1990-91, accordingly, consisted of changes in temporary or visiting members of the research staff holding short-term appointments. The appointment of Vladimir Bellruss as research affiliate without salary was extended for one year. Appointments as visiting scientists (without salary) were extended to Takahiro Hyuga (working with Professor Bernhardt Wuensch), Kazuyoshi Kuriyama (working with Professor Mildred Dresselhaus), Jong Tae Park (working with Professor Clifton Fonstad), and Alexander I. Zagumennyi (working with Dr. Hans Jenssen). In addition, Dr. Somnath Sengupta was appointed a postdoctoral assistant in the Crystal Growth Facility in December of 1990. The appointment of Mark Garrett as a postdoctoral associate in the Crystal Growth Facility was extended; he had been appointed earlier to fill a vacancy left by the resignation of a research specialist. Another member of the Crystal Growth Facility staff, Dr. David Gabbe, a research scientist, was transferred to CMSE from the Department of Materials Science and Engineering on February 1, 1991. Joseph Peidle, who served as manager of our Synchrotron Radiation Facility at

Brookhaven National Laboratory, resigned. He was replaced by René Holaday, who was appointed on January 1, 1991.

CURRENT RESEARCH

The general areas of CMSE research, a few highlights of the accomplishments during 1990-91, and a list of faculty participants and their departmental affiliations are briefly described in the following sections. Research was conducted in four areas-of-thrust under the MRL grant for the three years that concluded at the end of February 1991. Under the new program cycle that commenced on March 1, 1991, work began in a new thrust devoted to study of grain boundary structure and properties. One of the four earlier thrusts, that concerned with deformation and fracture of intermetallic compounds, will not be continued beyond the first year of the new program. Brief mention of the single-investigator seed grants is also provided, as well as work performed in the Laboratory for Advanced Solid State Laser Materials that is administered by CMSE.

Transition Metal Oxides

Research in this thrust area is concerned with superconductivity with high critical temperatures in oxide materials. The thrust was initiated shortly after the discovery of superconduction in La_2CuO_4 and has completed its third year of activity. Early success in growth of the first large single crystals of this material in our Central Facility for Crystal Growth permitted Professors Robert Birgeneau and Marc Kastner to perform key neutron scattering studies that revealed that antiferromagnetic correlations between the Cu moments figure prominently in the origin of the superconductivity. Professors Birgeneau and Kastner have continued their studies during the past year and have found highly unusual inelastic scattering by the magnetic fluctuations, different from that in all previously studied systems. The scattering was found to scale with energy transfer and inversely proportional to absolute temperature. Other work within this thrust was concerned with processing of this family of superconductors and fabrication of thin film devices. Professor Terry Orlando succeeded in fabricating the first known superconducting quantum interference devices (SQUIDs) from sputtered films of the bismuth-containing superconducting oxides to produce devices that displayed extremely low flux noise. Professor Yet-Ming Chiang has examined alternate processing routes for the preparation of thin films in this system, namely spin coating and pyrolysis of liquid citrate precursors. Fabrication of bulk material has been accomplished by Professor Vander Sande in a unique process that was awarded the first US patent for fabrication of superconducting oxides. The metal atoms in the material are prepared in a homogeneous metallic form through rapid solidification methods. The broad scope of the thrust, encompassing theory, fundamental studies of the mechanism of superconductivity, fabrication of thin film devices, and the novel synthesis and characterization of polycrystalline bulk materials, was entirely appropriate in the early days of high- T_c superconductivity. With proliferation of oxide phases of ever-increasing structural and chemical complexity and progressively higher critical temperatures, it seemed appropriate to focus the activities of the thrust more tightly. The discovery of new materials Nd_2CuO_4 and Pr_2CuO_4 that, when doped with Ce, display superconductivity in which charge appears to be conducted by electrons rather than holes, led to the organization of a smaller and more coherent thrust centered on fundamental studies of the mechanisms that underlie superconductivity in simple ternary oxide materials. The investigations of Professors Chiang, Dresselhaus, Orlando, Harry Tuller, and Vander Sande were accordingly not continued beyond the start of the new program cycle on March 1. Two additional faculty, previously supported with CMSE seed funding, were added to the team. Professor John Graybeal has prepared single-crystal deposits of NdCuO_4 for measurement of optical properties and tunneling behavior in the material, both of which can be studied only in specimens in the form of thin films. Professor Hans-Conrad zur Loye, a solid-state chemist, has explored synthesis of new families of transition metal oxides.

Participating faculty and departmental affiliation; through March 1, 1991: Professors Y.-M. Chiang, H. L. Tuller, and J. B. Vander Sande (Materials Science and Engineering); M. S. Dresselhaus and T. P. Orlando (Electrical Engineering and Computer Science). Beginning March 1, 1991: Professors J. M. Graybeal (Physics) and H.-C. zur Loye (Chemistry). Continuing thrust members: R. J. Birgeneau, M. A. Kastner, P. Lee (Physics), and H. P. Jenssen (CMSE Principal Research Scientist).

Phases and Phase Transitions

The research of this thrust involves the study of structured fluids—liquid crystals, micelles, microemulsions, and gels. Experimental study has been made of the structure of phases and their properties in the vicinity of order-disorder phase transitions. The principal techniques that have been utilized are precise calorimetry and

scattering studies that employ light, X-rays, and neutrons as probes. Statistical mechanics is used to develop theoretical models to describe the behavior of these phases. Professor A. Nihat Berker has, during the last year, developed a model for highly polar molecules that incorporates dipole-dipole interactions, van der Waals interactions, and benzene-ring rotational hindrances. The model has provided a successful description of the microscopic mechanism for some of the phase transformations observed in these systems. The propagation of layer tilt in smectic C ordering has been shown to occur via the locked-in relief of two separate frustrations due, respectively, to the dipole interactions and to benzene-ring steric hindrances. The theory also explains nematic-smectic A_d -nematic reentrance by the high entropy content of the smectic A_d phase. Experiments on frustrated smectic liquid crystals have been conducted by Professor Garland. Very good agreement is obtained between experiment and theory with respect to phase diagram reentrances, as well as properties such as specific heat and layer thicknesses. Professors Birgeneau and David Litster have continued their study of the crossover from three-dimensional to two-dimensional behavior of crystals of smectic phases that may be prepared in the form of free-standing films that range down to as few as two molecular layers in thickness. A combination of X-ray scattering and light scattering is used for detailed investigation of these materials. Professor Sow-Hsin Chen has used small angle neutron scattering to study microemulsions. These are molecular mixtures of water, oil, and surfactant in which there exist large-scale self-organized surfactant layers. For a combination of water, oil, and surfactant in particular proportions, an unusual phase transformation occurs as temperature is varied. A water-in-oil microstructure inverts to an oil-in-water microstructure. Professor Chen has successfully modeled the bicontinuous transition microstructure at which the hydrophilicity and hydrophobicity of the surfactant molecule toward water and oil are exactly balanced. Professor Daniel Blankshtein has worked toward development of a theoretical description of the phase behavior and phase transitions of multicomponent micellar solutions at the molecular level. Previously supported with seed funding, he has developed strong collaborations with Professor George Benedek, as well as Professor Chen, and was incorporated as a full member of the thrust as of March 1. Professor Kardar, principal investigator of another seed project, has also been incorporated as a member of the thrust at the outset of the new program year. His theoretical work on fluctuations and transformations of surfaces ranges from interactions with Professors Birgeneau and Litster on the heat capacity and scattering behavior of thin films of the hexatic liquid crystal phase, to study of tethered surfaces with Professor Toyochi Tanaka.

Participating faculty and departmental affiliation: Professors C. W. Garland (Chemistry); G. B. Benedek, A. N. Berker, R. J. Birgeneau, J. D. Litster, and T. Tanaka (Physics); and S. H. Chen (Nuclear Engineering). Faculty beginning March 1, 1991: D. Blankshtein (Chemical Engineering) and M. Kardar (Physics).

Synthesis, Properties, and Morphology of Novel Polymers and Block Copolymers

Seven investigators, drawn from four departments, collaborate in the chemical synthesis of novel polymers and block copolymers and in the investigation of their electrical, optical, and mechanical behavior. Professors Ali Argon and Robert Cohen have studied glassy thermoplastics toughened with appropriate rubbery agents. A new toughening mechanism was discovered in which crazes are locally plasticized by an enhanced solubility of the rubber created by negative pressure. This causes lowering of the craze yield stress, thereby increasing the craze lifetime and producing enhanced toughness. The basis of many new polymers examined by the thrust is a remarkable synthesis route developed by Professor Richard Schrock. Transition metals are used to catalyze a ring-opening metathesis reaction. The polymer produced is highly unusual in that control of the reaction permits production of a polymer of precisely defined chain length. In a continuing collaboration, Professors Schrock, Cohen, and Robert Silbey have used the procedure to synthesize block copolymers containing metal atoms. When static cast from benzene or toluene, the copolymers exhibit microphase separation, driven by the strong dissimilarity in the structure of the repeat units. The morphology can be spherical, rodlike, or lamellar, depending on the respective molecular weights of the two blocks. The metal complex (for example, of nickel, palladium, platinum, or gold) is confined to one of the microregions and can be converted to metallic clusters by a mild treatment at 100-120°C in hydrogen for a few days. The intervening metal-free domains act as barriers to cluster aggregation so that particles are produced only within those domains that originally contained the metal complex. The size distribution of the particles is quite narrow, ranging 20-40Å. The density of the clusters may be varied by changing the weight percent of the metal complex. Small metal clusters of this size range exhibit chemical and physical properties that are quite distinct from those of bulk material and are currently of great interest. Methods for the synthesis of clusters with a narrow distribution about a desired specific size are, however, quite scarce. Professor Edwin Thomas became a new member of the thrust area group in March 1991. Supported during the previous year with seed funding, his work has involved the application

of high-resolution electron microscopy and electron diffraction to the study of polymer morphology and molecular packing at crystal-crystal boundaries.

Participating faculty and departmental affiliation: Professors R. R. Schrock, R. J. Silbey, and M. S. Wrighton (Chemistry); R. E. Cohen (Chemical Engineering); M. F. Rubner and E. L. Thomas (Materials Science and Engineering); and A. S. Argon (Mechanical Engineering).

Deformation and Fracture in High-Temperature Materials

Increasingly higher operating temperatures provide improved performance of power generation systems and aircraft turbine engines. This creates continuing demand for new materials with higher melting temperatures and lower densities and a need to improve incrementally existing structural materials to permit their application under more stringent conditions. Six investigators from the Departments of Materials Science and Engineering and Mechanical Engineering have performed studies of performance-limiting phenomena such as microstructural stability, creep resistance, cyclic deformation resistance, ductility, and fracture structure. Professors Samuel Allen and Frank McClintock have collaborated in using transmission electron microscopy to observe the dislocation arrangements in deformed crystals of NiAl, and to relate these structures to the deformation-induced surface roughening that occurs when this material is applied as a coating. Professors Argon and David Parks have developed a model for creep damage by intergranular cavitation that is applicable to relatively ductile polycrystalline alloys such as single phase type 304 stainless steel. Mechanistic modeling of intergranular cavitation by diffusional flow in the presence or absence of grain boundary sliding provided a flexible means of accurately calculating the evolution and spreading of creep damage at blunt notches and/or sharp cracks.

Participating faculty and departmental affiliation: Professors S. M. Allen and R. M. N. Pelloux (Materials Science and Engineering); A. S. Argon, L. Anand, F. A. McClintock, and D. M. Parks (Mechanical Engineering).

Structure and Transport Properties of Grain Boundaries and Interfaces

The vast majority of materials in technology are polycrystalline and often polyphase. Given the importance of grain boundaries and interfaces, it is remarkable that so little fundamental understanding exists on the atomic structure, chemistry, and physical properties at such interfaces. A principal barrier to understanding is that an interface is essentially a two-dimensional entity, being in most instances only a few atomic layers in thickness. Few techniques have been available until recently for characterization of two-dimensional structure or chemistry on an atomic scale. The situation has changed dramatically with the development of transmission electron microscopy to levels of resolution that permit one to examine directly nonperiodic structure on an atomic scale, but also to obtain chemical analyses of regions of comparable dimensions. Other techniques, such as Auger electron spectroscopy, Rutherford backscattering, and secondary-ion mass spectrometry, are available that permit the determination of composition in regions adjacent to interfaces, again on the scale of the crystalline unit cell. Five faculty members are collaborating in this new area of thrust, initiated in March 1991, to determine structure, composition, and transport properties of grain boundaries in a high-purity oxide material. Professors Robert Balluffi and John Vander Sande combine an experimental and modeling effort to provide information on the atomic-scale structure of general grain boundaries. Professor Bernhardt Wuensch will fabricate oxide bicrystals of controlled orientation by means of chemical vapor transport techniques. The chemistry at the interface will be determined by Professor Vander Sande using scanning transmission electron microscopy, after which the same specimen will be employed for measurement of grain boundary self-diffusion rates. Professor Tuller will attempt to probe the electrical properties of individual grain boundaries in polycrystalline ceramics, as well as in bicrystals. Professor Chiang has been collaborating with Professor Vander Sande to make direct measurements of the magnitude of space charge field near the interface of the bicrystal with the aid of electron-optical methods. Ultimately, it is hoped to repeat these measurements in ultra-high purity oxide bicrystals fabricated with the aid of a dedicated molecular beam epitaxy apparatus that Professor Robert Balluffi is constructing expressly for this purpose.

Participating faculty and departmental affiliation: Professors R. W. Balluffi, Y.-M. Chiang, H. L. Tuller, J. B. Vander Sande, and B. J. Wuensch (Materials Science and Engineering).

Seed Research

A portion of the funding awarded under the Materials Research Laboratory Program supports research proposed by newly-appointed members of the faculty or projects supervised by more senior faculty that may

eventually be incorporated into one of the areas of thrust. In some cases, support of limited duration is provided for a feasibility study of a novel idea that holds great interest and promise, but also involves some risk. Proposals for seed research may be submitted to CMSE for consideration by the Internal Advisory Committee at any time, but are approved for funding only until the end of the current program. It is intended that, available funding permitting, newly-initiated projects will be funded through completion of the study. Renewal proposals for seed projects may thus be submitted, but are considered on a competitive basis with new proposals. Fifteen seed projects were funded for all or part of the year 1990-91. The seed-funded projects of Professors Blankschtein, Graybeal, Kardar, Thomas, and zur Loye, as noted in the preceding sections, were incorporated into thrust area research programs for continuation as a result of the relevance of these projects to the objectives of the thrust. Seed projects that were brought to conclusion include an elegant and detailed study of the rearrangement of atoms near surfaces performed by Professor Simon Mochrie at the CMSE Synchrotron Radiation Facility; a study of the behavior of the rigid amorphous component of polymers performed by Professor Peggy Cebe; and a project conducted by Dr. John Haggerty towards preparation of single crystals of refractory intermetallic compounds for study of their mechanical behavior. Professor Manual Oliveria has constructed a sputtering system that will allow the fabrication of magnetic materials with nanoscale microstructure. Professor Jesús del Alamo has attempted to demonstrate quantum effects in a new device termed the quantum field effect directional coupler. The device permits coherent quantum mechanical tunneling between two closely-spaced quantum wires. The degree of tunneling is controlled by a gate electrode positioned between the wires. Such tunneling currents were successfully observed during the past year; marked oscillations in the leakage current represent a direct mapping of the one-dimensional density of states in the quantum wire. It is noteworthy that the gate used to control interaction between the two wires was fabricated with a width of only 300Å. In other projects towards fabrication of nanoscale structures, Professors Kirk Kolenbrander and Mounji Bawendi have, in separate projects, examined methods for fabrication of small atomic clusters of semiconducting materials.

Participating faculty and departmental affiliation: Professors B. Altshuler, J. M. Graybeal, M. Kardar, and S. Mochrie (Physics); M. Bawendi, S. Buchwald, and H. zur Loye (Chemistry); D. Blankschtein (Chemical Engineering); J. del Alamo (Electrical Engineering and Computer Science); P. Cebe, N. Herbots, K. Kolenbrander, M. Oliveria, and E. L. Thomas (Materials Science and Engineering); and J. S. Haggerty (Sr. Research Associate, Materials Processing Center).

Laboratory for Advanced Solid State Laser Materials

Significant programs supported by the Office of Naval Research and the National Aeronautics and Space Administration have been, for some time, conducted by CMSE staff in close association with the Central Facility for Crystal Growth. To delineate clearly these non-MRL sponsored activities from the operation of the Facility for Crystal Growth, the above-named laboratory, under the supervision of Dr. Jenssen, was formally organized during 1990-91. The laboratory is concerned with the spectroscopy and physics of materials intended for solid state laser applications. Interest in high efficiency laser-diode pumped materials has created a need for new materials of good optical quality capable of lasing at longer wavelengths in the mid-infrared. The laboratory attempts to develop new materials, as well as producing known materials in single-crystal form, often for the first time. During the past year, significant accomplishments of the laboratory were the production of high-quality single crystals of Nd-doped BaY₂F₈. Crystals of Cr-doped LiSrGaF₆ were also produced and have lased successfully with high efficiency in even the preliminary tests.

CENTRAL FACILITIES

Until the start of the new program cycle of March 1990, CMSE operated 13 central research facilities. These laboratories, operated under the MRL Program, are available to qualified users throughout the entire MIT community, as well as to sister institutions and industry, provided that capacity sufficient to accommodate their work is available. Some of these facilities provide basic services such as chemical analyses and machining. Most, however, involve state-of-the-art, and often unique, apparatus that is too expensive for acquisition and maintenance by an individual research group. Modest user fees are imposed that permit partial recovery of operating costs, but not capital expenses. Through such subsidies, the CMSE program has an influence on research performed at MIT that extends well beyond the projects that CMSE supports directly. We estimate that on the order of two-thirds of the activity in our central facilities was conducted with non-MRL supported projects.

The instruments housed in the central facilities are regularly upgraded and updated. Some highlights of 1990-91 are the following. The increased demand for X-ray powder diffractometry experienced in the X-ray Diffraction Facility has led to the acquisition of an additional Rigaku RU-300 18kW rotating anode generator, that has been equipped with two Rigaku powder diffractometers. The capability of the Electron Microscopy Facility has been augmented in a major way through acquisition of three new state-of-the-art instruments. The first is an Akashi/ISI EM002B high-resolution transmission electron microscope that became fully operational in the summer of 1990. This instrument is capable of 1.8Å point-to-point resolution and thus permits microscopy on a scale that resolves individual atoms. The second instrument is a Vacuum Generators dedicated field-emission scanning transmission electron microscope. This instrument, the first of its kind, operates at 300 keV. The electron optics permit formation of a very fine electron probe 2Å in diameter; the much higher voltage reduces beam broadening in the sample, thus providing superior spatial resolution. The instrument permits quantitative chemical analyses of areas as small as 3Å in diameter. The third instrument is an Electroscan environmental scanning electron microscope. This instrument incorporates an entirely new process for image formation that eliminates the need for high vacuum in the specimen chamber. This provides two unique advantages. Surfaces of any type specimen, metallic or insulating, and in any state--wet, dry, or oily--may be directly examined, as opposed to current SEM practice in which one instead is forced to examine a conductive metallic crust that has been evaporated onto the specimen. Moreover, the instrument permits examination of specimens in atmospheres at pressures that range up to 50 torr.

Several central facilities have been consolidated or no longer directly receive a subsidy from CMSE. This reorganization was undertaken in the interests of efficiency and economy of scale, but was necessitated, in part, because of the constrained budget in effect for the MRL Program as of March 1991. Separate facilities for scanning electron microscopy and for transmission electron microscopy/scanning transmission electron microscopy had been operated by CMSE, in part for historic reasons and, in part, because the applications and technologies of these instruments were formerly quite distinct. It made sense for technical reasons to combine these facilities into a single Central Facility for Electron Microscopy. Administrative reorganization has already taken place, and the physical move will be undertaken in the near future. A Central Facility for Rapid Solidification was used primarily used by one research group. CMSE will continue to administer the facility, but will no longer support a laboratory supervisor; maintenance of the apparatus has been delegated to the research group. Several years ago, an electron microprobe operated by CMSE was transferred to a similar facility operated by the Department of Earth, Atmospheric, and Planetary Sciences (EAPS), where operation of both instruments could be overseen by a single laboratory manager. CMSE continued to provide a subsidy towards operation of that laboratory, but both discontinued this support and fully transferred the facility to EAPS as the laboratory appeared to be on solid footing and capable of providing this analytic service to the MIT community. The Polymer Central Facility (in which the most heavily used apparatus was a differential scanning calorimeter and solid-state nuclear magnetic resonance) has been combined with the Central Analytic Facility in a reorganized Facility for Chemical and Thermal Characterization. The capability for latter analyses has been significantly augmented by several state-of-the-art instruments that are capable of operation at temperatures in a range of interest to workers on materials other than polymers. The apparatus includes a Seiko DSC-320 high-temperature differential scanning calorimeter, a Seiko TG-DTA-320 thermogravimetric and differential thermal analyser, and a Seiko DMS 110-200 dynamic mechanical rheology station. As a result of these consolidations, CMSE, as of March 1991, operates nine rather than the 13 previous central facilities. Their operation and administration promises to be leaner and more efficient. Few essential services, however, have been lost to the materials community.

BERNHARDT J. WUENSCH

Division of Comparative Medicine

The Division of Comparative Medicine (DCM) provides animal husbandry and clinical care for all research animals on the MIT campus. From its inception in 1972, the Division has evolved into a comprehensive laboratory animal program that provides a full range of veterinary and surgical support. Additionally, the Division has a National Institutes of Health (NIH)-funded training program for veterinarians specializing in laboratory animal/comparative medicine and conducts externally funded research focusing on diseases of laboratory animals.

Facility Management and Animal Care

The average daily census of laboratory animals increased approximately 20 percent during FY91. Mice remain the primary species used by MIT investigators and represent more than 90 percent of the animal population. Using NIH grants totalling \$440,000 during the past two years, we completed a number of improvements and renovations in the animal facilities. New cage washers and autoclaves were installed in Buildings 56 and E17. A radiology suite has been completed in E20 and a unit for the housing of germ-free animals has been set up in E18. The new biology building slated for completion in 1993 will have a 30,000 gross-square-foot animal resource unit under the direction of the DCM.

Ms. Scarlett Nelson has been hired as the Division's new Animal Facilities Manager to oversee the operation of the animal facilities and to train the animal care staff consisting of 20 animal technicians, an assistant manager, and a facilities coordinator.

Research Activities

The DCM Diagnostic and Investigative Laboratory is in its 16th year of funding. This grant enables the Division to pursue research projects associated with diseases of laboratory animals and development of relevant *in vivo* models. Other NIH-funded grants support the study of nitrite carcinogenesis using animal models, the study of *Helicobacter pylori* and its relation to gastric cancer, and an examination of the intestinal metabolism of B-carotene. Private pharmaceutical firms have provided funding for the derivation of specific-pathogen-free ferrets and studies on cartenoid compounds in ferrets.

We have completed year three of our five-year NIH postdoctoral training grant. We currently have six postdoctoral trainees, two of whom will also be enrolled in graduate programs (one at Harvard and one at MIT). There is a strong demand for those who have completed our residency program in laboratory animal medicine. Two individuals completing their residency in July, 1991, were recruited into academic positions in medical schools.

DCM faculty and staff published 4 chapters, 30 papers and 31 abstracts in FY91. There are currently 4 chapters and 11 papers in press.

Regulatory Activities

The first Commissioner of Laboratory Animals for the City of Cambridge was hired during this past year. The Commissioner spent many hours examining the animal facilities, and reviewing animal care and use protocols. The USDA and Massachusetts Department of Public Health also made a number of unannounced inspections of the animal facilities. Our program continues to be in compliance with all regulatory guidelines. We are currently making cage modifications to comply with newly released regulations regarding the housing of primates and dogs.

Teaching Activities

DCM in conjunction with the Committee for Animal Care continues to conduct all-day training sessions for investigators and their staff. Investigators, research technicians and students were given practical training in various animal handling techniques during FY91 by DCM staff. Additionally, DCM faculty and staff taught the graduate course Toxicology 218 and also participated in Toxicology 210.

James G. Fox, DVM
Professor and Director

Energy Laboratory

INTRODUCTION

The Energy Laboratory and its associated Center for Energy Policy Research (CEPR) are multi-disciplinary organizations bringing together sectors of the MIT community with research interests related to energy supply, policy, technology, utilization, and the associated environmental, economic, geographical and societal impacts. Professor Jefferson Tester is the Director of the Energy Laboratory, supported by Associate Directors William Peters and Elisabeth Drake. Susan Guralnik is the Administrative Officer. The Energy Laboratory is saddened to report the sudden death on April 28 of David Wood, who so ably led the CEPR. Professor Richard Eckaus is currently serving as Interim Director of the CEPR, supported by Betty Jo Sheridan, Assistant to the Director. A search for a new Director is underway.

The Energy Lab offers the organizational structure needed for synergistic endeavors that both strengthen and focus energy-related work at MIT and provides a variety of research opportunities for students at all levels - from Undergraduate Research Opportunities Program to doctoral studies. Our research programs in FY91 involved about 50 undergraduates and 120 graduate students, along with 75 associated faculty members from some 14 Academic Departments representing all five of MIT's Schools. There is no formal academic curriculum, but many of the faculty associated with the Energy Lab teach courses and participate in formal and informal seminars related to energy technologies and their applications.

SELECTED CURRENT ACTIVITIES

Many of the Laboratory's projects involve quantitative and cross disciplinary study of complex energy and environmental systems. Collaboration with the Center for Environmental Health Sciences (directed by Professor Thilly) seeks to determine how combustion emissions may lead to adverse human health impacts. Other environmental research, in collaboration with the Parsons Laboratory (directed by Professor Bras) focuses on fate and transport of effluents from energy facilities. The Energy Lab administers two major experimental facilities for research on stationary and mobile combustors - the Combustion Research Facility (directed by Professor Beer) and the Sloan Automotive Lab (directed by Professor Heywood).

The Electric Utility Program, managed by Derek Teare, involves the collaboration of a group of major electric utility companies and some of their fuels and equipment suppliers to identify and fund research projects of mutual interest. Current research includes three major combustion-related projects in the Combustion Research Facility (Professors Beer and Sarofim) and twelve projects led by faculty and staff in the Laboratory for Electromagnetic and Electronic Systems on the behavior of electrical power apparatus and electric power systems. Other projects involve researchers from the Parsons Lab, the Nuclear Engineering Department and the Nuclear Reactor Lab. In another project, led by Professor David White, researchers use multi-attribute tradeoff analysis to compare alternative strategies that the New England electric utility sector might use to meet future energy needs. This project is guided by a diverse group of stakeholders including representatives of the utilities, regulatory groups and public interest groups. For Central Maine Power Company, a study of opportunities for energy conservation in the pulp and paper industry was conducted. Professor Norford is heading a project studying energy consumption in building heating and ventilating systems.

Other energy conservation initiatives range from industrial process improvements (Howard Herzog) to advanced building design (Professor Glicksman), including concerns about indoor air pollution (Professor Axley). Innovative deep rock drilling technology for exploitation of petroleum and geothermal energy requires both engineering (Professors Tester and Peterson) and earth sciences expertise (Professor Toksoz and Dr. Turpening). Another project addresses safe lifetime extension of nuclear power plants (Professor Hansen).

A major collaborative program between MIT and the Idaho National Engineering Laboratory seeks new engineering understanding to improve efficiency and materials conservation in energy-intensive processes. This program is directed by Professor White and involves faculty from several MIT departments. Electrochemical energy conversion is another interest along with other topics involving fuel conversion research (Professors Howard, Longwell, Sarofim and Tester; and Dr. Peters).

Environmental issues of global warming, acid rain and localized pollution effects drive much of our research on new energy sources, technologies and policies (Professors White and Sarofim). Our close association with the CEPR facilitates technological research within the context of policy-related issues.

THE CENTER FOR ENERGY POLICY RESEARCH

The CEPR is organized as a joint center of the Energy Laboratory, the Department of Economics, and the Alfred P. Sloan School of Management. CEPR projects are currently organized under six program areas: 1. investment, contracting, and finance, 2. international energy markets, 3. energy industry organization and regulation, 4. energy demand, productivity, and economic growth, 5. technology policy, and 6. environmental economics, management and policy. The Center's program on environmental economics, management and policy is developing rapidly and has nine active research projects in this area. Toward that objective, the CEPR and the University of Tokyo Global Environmental Study Laboratory co-hosted a *Workshop on Economics/Energy/Environmental Modeling for Climate Policy Analysis* on October 22-23, 1990. The purpose of the workshop was to present and discuss international policy modeling research programs and studies aimed at increasing understanding of the economic consequences of climate change and of policies to adapt to, or mitigate, climate change. During 1990, the CEPR published and distributed six working papers and released seven reprints of published papers.

NEW INITIATIVES

In collaboration with other groups at MIT, the Energy Lab is developing funding for several new projects in the following areas: treatment technologies for Department of Defense wastes and management of environmental remediation activities at Department of Energy sites (Professor Hansen and Dr. Weiss); fuels technology, including fuel cells, high temperature/plasma reactions, oxidation in supercritical water, and hot dry rock geothermal developments (Professors Beer, Howard, Longwell, Sarofim and Tester; Dr. Peters); industrial ecology using life cycle analysis of technological alternatives considering environmental, safety and economic trade-offs; and the interfaces between global change science, policy and technology (Professor White and Dr. Drake). Also, during FY91, the Sloan Automotive Lab launched a new consortium to study how reformulated fuels will affect engine performance and emissions. These endeavors are receiving encouraging responses from several potential new sponsors.

MAJOR PUBLICATION

In April 1991, the MIT Press released a 1000-page book, *Energy and Environment in the 21st Century*, edited by Professor Tester, David Wood and Nancy Ferrari, based on the proceedings of the conference organized by the Energy Lab at MIT a year earlier. The comprehensive nature of this book reflects the diversity of capabilities within the Energy Lab and CEPR, as well as their associated national and international professional networks.

FINANCIAL OVERVIEW

The estimated research volume for the Energy Laboratory in FY91 is \$9.0 million, down slightly from FY90. The distribution by research area is approximately as follows:

- Combustion and fuels research - 15 percent
- Electric power equipment and systems - 12 percent
- Health and toxicological effects of energy use - 15 percent
- Transportation propulsion - 12 percent
- Energy engineering and materials - 17 percent
- Nuclear Systems - 10 percent
- Energy economics, management and policy - 8 percent
- Other - 11 percent

JEFFERSON W. TESTER

Harvard-MIT Division of Health Sciences and Technology

INTRODUCTION

The Harvard-MIT Division of Health Sciences and Technology (HST Division) links the educational resources of Harvard University and MIT in order to provide unusual educational and research opportunities to highly talented students who desire an education at the interface of technology and the medical sciences. The PhD Program in Medical Engineering and Medical Physics equips highly qualified engineers and physical scientists for independent research careers working on problems of significance to human health. The joint HST/Nuclear Engineering Department Doctoral Program in Radiological Sciences is designed to produce individuals who are well-prepared to investigate problems in radiation therapy or in biomedical imaging sciences. The MD curriculum seeks to train physician/scientists. It provides a rigorous quantitative education in human biology, pathophysiology and clinical medicine, and, at the same time, emphasizes the importance of independent research.

ADMINISTRATION

The HST Division continues to be administered by two co-directors who work intimately with MIT Associate Provost and Vice President for Research, J. David Litster, and Harvard Medical School Executive Dean for Academic Programs, James Adelstein. Roger G. Mark, Grover Hermann Professor of Health Sciences and Technology, is the MIT co-director. In the summer of 1990, Dr. Richard Kitz, after five incredibly fruitful years of association with HST as its co-director, relinquished that role in order to devote full-time attention to the direction of the Department of Anaesthesia at the Massachusetts General Hospital. Dr. Walter Abelmann has accepted the responsibility of interim co-director of HST. He has long played a central role in the guidance of HST's MD program as a major course director, and as an administrator concerned with the curriculum, the thesis program, and the faculty advisory structure. A search for the Harvard co-director of HST, who will occupy the Ebert Professorship in Molecular Medicine, is nearing completion, and a permanent co-director is expected to be appointed in the near future.

The MIT Clinical Research Center, directed by Professor Richard Wurtman, was administratively included in the HST Division in the fall of 1990. We anticipate that this new association will stimulate increased utilization of the excellent facilities of the CRC by members of HST-affiliated faculty.

ACADEMIC PROGRAMS

A total of 213 graduate students were registered in HST degree programs during the past academic year. 169 were MD candidates of whom 78 were simultaneously pursuing PhD degrees. There were 56 students registered in the Doctoral Program in Medical Engineering and Medical Physics. One student was registered for the doctoral degree in Applied Biology in Medicine, and 2 students were enrolled in the Radiological Sciences Graduate Program.

18 HST students received the MD degree during this academic year, and 3 students received PhD degrees in Medical Engineering/Medical Physics. It is of significance that approximately 76% of the MD students were receiving partial support through research and/or teaching assistantships.

FACULTY AND STAFF

Dr. Linda Cima was appointed as Assistant Professor of Health Sciences and Technology and Chemical Engineering beginning January, 1991.

Dr. Elezar Edelman was appointed as Assistant Professor of Health Sciences and Technology and Medicine beginning July 1, 1991.

Dr. Peter Reich, Chief of Psychiatry of the MIT Medical Department, has assumed responsibility as Chairman of the HST/MD Faculty Board of Advisors.

The Irving M. London Teaching Award was given to Dr. Helmut Rennke for his excellence in teaching renal pathophysiology.

Assistant Professor Martha Gray, and Assistant Professor Linda Cima were each recipients of NSF Presidential Young Investigator Awards this year.

Frederick J. Schoen, MD, PhD, has been appointed as Lawrence J. Henderson Associate Professor of Health Sciences and Technology. Dr. Schoen is Associate Professor of Pathology at Harvard Medical School and heads the Cardiac Pathology Division at Brigham and Women's Hospital. He is course director of HST 030, Human Pathology.

ROGER G. MARK
WALTER H. ABELMANN

Clinical Research Center

The Clinical Research Center (CRC) was established in 1964, with grant support from the National Institutes of Health (NIH), to provide a facility in which Massachusetts Institute of Technology (MIT) investigators and their collaborators could apply the Institute's expertise in basic biochemical and biophysical mechanisms to the analysis of normal and pathologic processes in humans. Although the CRC was the first federally supported clinical research center located in a university and not within a hospital, it was anticipated that a large enough number of qualified physicians from MIT's faculty and staff would become involved in the CRC's activities in expanding the kind of research that MIT-based investigators could explore.

For most of its history, the CRC was administratively located within the Department of Nutrition and Food Science (or later, Applied Biological Sciences), and the primary research interest of most of its principal investigators was nutrition/metabolism. These activities included determining human protein requirements under various conditions (for example, high physical activity); exploring the utility of artificial protein sources; and characterizing circadian rhythms in, and meal effects on, plasma amino acid patterns. Research in this general area remains a CRC commitment, particularly the focus on amino acid metabolism. However, from its inception, the CRC also supported an active program in the clinical neurosciences, starting with the still ongoing studies on the cognitive and sensorimotor consequences of brain trauma, directed initially by Professor Hans-Lukas Teuber, and now by Professor Suzanne Corkin. In 1981 the CRC became an independent entity within the School of Science, and in July, 1986 it was incorporated within the Whitaker College, reporting to the Director of Whitaker College and Associate Provost, Professor Kenneth Smith.

In September, 1990, the CRC was made a component of the Harvard-MIT Division of Health Sciences and Technology (HST) and reports to its Director, Professor Roger Mark, who is also the Principal Investigator of the CRC's NIH grant. This integration, which relates to the CRC's academic programs, will provide the CRC with access to a relatively large number of MIT faculty and research staff who are committed to research on humans. It will also enhance the availability of the CRC's facilities to HST personnel, both for the conduct of research and ultimately for training opportunities.

Scientists and physicians authorized to carry out research protocols using the CRC's facilities include: professors; research scientists who work exclusively at MIT; and those with primary appointments in local medical institutions whose research interests overlap extensively with those of MIT investigators. Research protocols must be approved by the MIT Committee on the Use of Humans as Experimental Subjects (COUHES) and the CRC Advisory Committee before they can be implemented.

The CRC Advisory Committee, chaired by Jack Burke, M.D., Professor of Surgery at Harvard Medical School, and consisting of ten voting members plus 6 non-voting members of the CRC's Program Staff, reports to the Principal Investigator, Professor Roger Mark. The Committee meets bi-monthly and evaluates protocols for their scientific quality, experimental design, statistical analysis and potential risk to human subjects. Protocols may be approved contingent on minor modifications; deferred; or disapproved. The Advisory Committee also sets general policies and reviews the operations of the CRC.

ADMINISTRATION

The CRC presently has a dual administrative locus within MIT. As a research unit the CRC reports through HST to the Associate Provost and Vice President for Research, Professor J. David Litster. However, as a patient-care unit, the CRC is a part of the MIT Medical Department, and all CRC committees and functions concerned with patient care and quality assurance report to the Medical Department or have been incorporated with the Medical Department's own system.

The CRC is administered by a Director (Professor Richard J. Wurtman), an Associate Director (Professor Naomi K. Fukagawa); three Assistant Directors (Drs. David August, William H. Dietz, and Merton Kahne); and Dr. Elaine Shiang who acts as the liaison between the Medical Department and the CRC. The Assistant Directors are all physicians who have completed residency training in medical specialties (medicine, psychiatry, pediatrics) and have also had advanced research training, usually leading to a Ph.D. degree. Their appointment as Assistant Director allows them both to cultivate their own research interests, often at an important early stage in their career, and to

serve the CRC (for example, facilitating the conduct of clinical research by other MIT faculty who lack medical training).

RESEARCH ACTIVITIES

During the past year, most of the research activities of the CRC have continued to be associated with three clinical areas, and to involve three groups of scientists each led by a senior professor. These areas are: **Nutrition/Metabolism** (Professor Vernon R. Young) - an area in which the CRC constitutes the major locus of MIT's activity, and one that is a traditional component of clinical research centers; **Neurochemistry/Neuropsychopharmacology** (Professor Richard J. Wurtman) - studies on the effects of drugs, foods and hormones on brain composition and behavior; studies on biologic rhythms in sleep and hormone secretion; studies on a set of diseases characterized by affective and appetitive symptoms (i.e., depression, pre-menstrual syndrome, smoking withdrawal, carbohydrate craving, obesity), which seem to relate to brain serotonin; and **Behavioral Neuroscience** (Professor Suzanne Corkin) - focussing on the effects of diseases on cognitive and related brain functions and on genetic and other mechanisms causing neurodegenerative disorders (i.e., Alzheimer's disease). Groups collaborate on multidisciplinary projects, e.g., Obesity; Depression; Alzheimer's disease. Moreover, numerous CRC research collaborators involve both an MIT professor and investigators at an outside hospital or research laboratory.

Besides these three established programs, CRC investigators have conducted research projects involving the development of biomedical instrumentation; the analysis of human autonomic functions (e.g., the contribution of the sympathetic and parasympathetic systems in generating particular electrical frequencies detected by the electrocardiogram); visual changes resulting from neonatal effects of sex hormones on the brain; and sensorimotor disturbances. Such projects are especially germane to an institution with the resources of MIT, and the CRC directorate is committed to facilitating their development.

The uniqueness of the CRC relates to the fact that it is MIT's sole locus for carrying out investigations which require the use of medical procedures; for example, venepuncture; special diets; nutritional balance studies; hormone or drug infusions; and frequent examinations or monitoring over a prolonged period. The CRC also houses laboratories for quantifying behavioral and cognitive functions, for making on-line measurements of elective nutrient intake, and for developing new devices for ensuring particular physiological parameters. Its infusion facilities are in daily use for administering deuterated metabolites, or for conducting insulin clamp studies.

For the time period July 1990-June 1991 utilization at the CRC totaled 398 inpatients and 4402 outpatients.

Nutrition and Metabolism

Protein and Amino Acid Metabolism in Healthy Adults

During the past year Professor Young and his associates have continued to expand upon tracer methods and improve models for exploring quantitative aspects of whole body amino acid metabolism and its regulation in adult humans. Considerable progress has been made in developing a model for the study of arginine and ornithine metabolism in man. Using ^{15}N -guanido-5- ^2H -arginine and 5- ^{13}C -ornithine and a new GC/MS method for determination of their enrichment in blood plasma they have confirmed through *in vivo* studies that arginine metabolism is strictly compartmented, both in terms of its interorgan and intracellular organization. This novel tracer model is now being applied to study *in vivo* arginine synthesis and its regulation by dietary factors. Additionally, they have completed a "long-term" metabolic study that provides additional and strong support for our earlier hypothesis concerning the gross inadequacy of current, international estimates of the amino acid requirements of adult humans. They continue to investigate the experimental and metabolic reasons for the discrepancy. These studies are providing a more secure and biologically rational basis for an understanding of the amino acid needs in health and, in consequence, for defining the quantitative significance of various pathophysiological factors on human amino acid metabolism and their nutritional significance.

Regulation of Energy Metabolism in Young and Older Adults

It has been hypothesized that adaptive thermogenic mechanisms serve to regulate body energy balance in healthy adults and also that these may be impaired in pre-obese and obese subjects and change with advancing adult age. Dr. Young and his associates have completed two, precise metabolic studies in healthy young adults and elderly individuals. Using the doubly-labelled water method to quantify total energy expenditure, coupled with

measurements of basal metabolic rate, thermic effect of food and body composition parameters, they did not find evidence of quantitatively significant adaptive thermogenesis to either a moderate excess (1,000 kcal per day) or restriction (800 kcals per day) in energy intake in young adults. Preliminary results for the elderly would appear to support a similar conclusion. Their studies emphasize the importance of energy balance in apparently healthy, normal adults.

Nutrition and Aging

Professor Naomi Fukagawa has continued to investigate metabolic regulation and nutrition in aging humans. Findings in 68 men and women in two age groups demonstrate that aging *per se* in humans is associated with altered tissue energy metabolism. The mechanism of this alteration is under investigation; recognition of it may influence our nutritional management of older individuals. Dr. Fukagawa's recent work has also shown that old men and women have thermic responses to oral protein which are similar to those of young men. This suggests that it is nutrient composition of test meals which determines differences in thermic responses, not body size, body composition or antecedent dietary intake. These findings may influence future study design.

The influence of dietary salt intake on protein-induced changes in renal function has also been explored, partly because of growing concern about dietary salt and disease processes, such as hypertension, commonly affecting the older population. These studies also examine relationships between renal dopamine production and protein-induced diuresis and natriuresis in aging humans. Aging was associated with an overall lowering of renal dopamine production, however, excretory responses to protein in both young and old were not affected by antecedent dietary sodium intake. High dietary Na⁺ increased Na⁺ and water excretion but did not affect urinary dopamine excretion.

Prospective Study of Obesity

Dr. William Dietz and his associates have screened 64 girls for the prospective study of the effects of energy expenditure on the development of obesity. Screening includes a measure of height, weight and triceps skinfold and familiarization with the equipment for indirect calorimetry. Six girls with a triceps skinfold greater than 85% do not qualify and are given the opportunity to participate in an alternative study. Of the 55 girls screened 21 qualify and to date 21 have enrolled in the prospective study.

Each subject has had a measure of basal metabolic rate and body composition by isotope dilution, anthropometry and impedance. In addition, subjects kept records of activity and food intake during the two-week period and were asked to fill out questionnaires regarding activity patterns and food intake. These prospective data on body composition and energy expenditure will be used to validate the activity and food questionnaires and records. Each girl also had maximal energy expenditure measured in order to determine the relationship of fatness to fitness. Heights and weights have been obtained from parents to determine the effect of parental obesity on various components of energy expenditure.

Neurochemistry - Psychopharmacology

1) Studies directed by Drs. Judith Wurtman, Bonnie Spring, and Richard Wurtman examined the involvement of brain serotonin in the behavioral syndrome that often follows smoking withdrawal and which - by leading to weight gain - often causes people to resume smoking. This syndrome includes changes in mood (hostility; aggression; sometimes depression) and in appetite (selective craving of carbohydrate-rich, protein-poor snacks), a constellation which we had previously noted in other clinical conditions (e.g., seasonal affective disorder; premenstrual syndrome; obesity with carbohydrate craving) that appear to depend upon brain serotonin (and which can be ameliorated by drugs that selectively enhance serotonin-mediated neurotransmission). In initial experiments, female subjects received one serotonergic drug (dexfenfluramine, 30 mg/day) or a placebo for the first 29 days after nicotine withdrawal, and various indices of mood and appetitive status were measured. It was found that subjects receiving placebo exhibited carbohydrate craving, weight gain, and objective changes in mood indices. These were fully blocked for the duration of the study by dexfenfluramine. A larger study is now underway in which placebo-treated patients are compared with those receiving each of two serotonergic drugs (dexfenfluramine or fluoxetine, 40 mg/day; three months).

2) Drs. Harry Lynch, Andy Dollins, and Richard Wurtman are extending available information of the effects of orally-administered melatonin (a hormone released at nighttime by the pineal gland) or of nocturnal exposure to light of sufficient intensity to suppress melatonin secretion, on plasma melatonin levels and on various behaviors which

may be influenced by the hormone. Initial studies examined three different ambient light intensities; dose-related decreases in nocturnal plasma melatonin levels were noted, and there may have been parallel changes in behavioral indices of vigilance (data are still being analyzed). Subsequent studies, still underway, are examining the effects of one of three oral doses of the pineal hormone (10, 20, or 40 mg). Previous studies showed that 80 mg doses made people sleepy, if given in the middle of the day; however these doses caused thousand-fold increases in plasma melatonin levels. It will be of interest to determine whether the lowest effective doses (in promoting sleep) produce melatonin levels in the range normally present at nighttime.

3) Drs. Richard Wurtman, John Growdon and Elliot Berry continued studies on the potentiation of the efficacy of L-dopa in Parkinson's Disease. They demonstrated that meals or snacks composed of the proper proportions of carbohydrates (with or without fats) and proteins can, by stabilizing plasma levels of the large neutral amino acids, minimize the fluctuations in the clinical responses to L-dopa. (Proteins alone diminish the drug's efficacy by raising plasma levels of the large neutral amino acids which compete with L-dopa for transport across the blood-brain barrier: carbohydrates lower their levels, causing too much L-dopa to flood the brain, leading to toxic symptoms.)

Behavioral Neuroscience

The Behavioral Neuroscience Laboratory under the direction of Professor Suzanne Corkin continues the analysis of brain-behavior relations in two domains: (1) the functional consequences in sensory systems of the distribution of lesions in Alzheimer's disease; and (2) the identification and characterization of multiple substrates underlying different types of learning and memory in humans. The latter project is funded by a MERIT award, which has been approved for a second five-year period. Professor Corkin serves on the Medical and Scientific Advisory Board of the Alzheimer's Association, she chairs the Nominating Committee, and she is secretary of the Executive Committee. This year, Professor Corkin was named a Fellow of the American Association for the Advancement of Science.

OTHER ACTIVITIES

The CRC has continued to provide postdoctoral training for physicians who are participating in fellowship programs at MIT. These physicians have utilized the CRC's facilities to initiate research protocols and to participate in ongoing projects supervised by senior investigators and faculty. During 1990-91 there was one graduate student and 16 post-doctoral fellows appointed at the CRC, (through the Department of Brain and Cognitive Science, the Whitaker College and the MIT-Harvard Division of Health Science and Technology). At the undergraduate level three Undergraduate Research Opportunities Program (UROP) students participated in clinical research projects with physician preceptors and faculty supervisors.

Professor Vernon Young was elected to the National Academy of Sciences in recognition of his work, much of which was conducted at the CRC.

The CRC, as part of the Medical Department, was surveyed by the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) on October 15-16, 1990 and accreditation was received for a period of three years until November, 1993.

RICHARD J. WURTMAN

Mining and Mineral Resources Research Institute

The Mining and Mineral Resources Research Institute (MMRRI) of MIT is a focal point for mineral-related activities at MIT. These activities are in two major areas, mining and metallurgy. The Departments of Civil Engineering, Mechanical Engineering, and Materials Science and Engineering are all involved in mining, while metallurgy is concentrated in the Department of Materials Science and Engineering.

The MMRRI of MIT is affiliated with the Mineral Resources Program of the Bureau of Mines of the US Department of the Interior, and participates in the research programs of the Generic Mineral Technology Centers for Pyrometallurgy and Respirable Dusts of the Bureau. It is also associated with the program of research and development on innovative methods for the production of iron and steel that is jointly supported by the American Iron and Steel Institute and the US Department of Energy. In the mining area, relations with the outside include, in addition to the Respirable Dust program, participation in MERI (Mining and Excavation Research Institute).

Within MIT the MMRRI represents the research component of the mineral resources efforts, while the MREM (Mineral Resources Engineering and Management Program) represents the educational component.

The annual allotment grant from the Bureau of Mines to the MMRRI of MIT is used, where possible, for the support of new initiatives related to mineral resources; to integrate the various research efforts in these areas; and to integrate research and educational activities. The funds are used to support undergraduates in their work in the REMERGENCE (Resource Extraction, Materials and Energy, Reservoir, Geotechnical, Environmental, and Construction Engineering) Laboratory, and several graduate and undergraduate students in the Departments of Civil Engineering, Mechanical Engineering, and Materials Science and Engineering. Limited funds are also utilized to purchase capital equipment for mineral-related research activities in these departments.

Personnel of the MMRRI provided technical leadership for the successful start-up and operation of a 1.5 megawatt plasma arc test facility in Charleston, SC. This facility, which is managed by the South Carolina Research Authority, demonstrates the technical feasibility of smelting fine chromium ores available to American industry. Phase II of the program has been funded by the Strategic Materials Office of the Defense Logistics Agency and involves the design, construction, and testing of a 12 megawatt demonstration plant at the Macalloy Corporation. The Phase I test facility will now be used for several follow-on plasma smelting evaluations including tests on the smelting of Taconite tailings, Alaskan chrome ores, and silicon/ferrosilicon. Thus, MIT's MMRRI initiative in this area is moving toward the practical implementation of advanced technology within the ferroalloys industry.

MERTON C. FLEMINGS

Northeast Radio Observatory Corporation/ Haystack Observatory

The Haystack Observatory is a research center engaged in radio astronomy, geodesy, atmospheric science, and radar applications. Parts of its programs are conducted under the auspices of the Northeast Radio Observatory Corporation (NEROC), a consortium of thirteen educational and research institutions* in the northeast. The Observatory receives financial support from the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the Department of the Air Force through MIT Lincoln Laboratory, as well as from other federal agencies and national programs.

The Observatory instrumentation at Haystack consists of a 37m diameter paraboloidal antenna enclosed in a radome that is used for radio astronomical observations at wavelengths from 6 mm to 18 cm, and is being upgraded for operations in the 3mm-wavelength band. In March 1991, the telescope saw first light at 2.6 mm-wavelength and 3.5 mm-wavelength with observations of the carbon-monoxide line and silicon-monoxide maser emission line from several radio sources in our galaxy. Observatory instrumentation also includes the 18m radio telescope at Westford which operates at 3.5 and 13 cm wavelengths for geodetic Very Long Baseline Interferometry (VLBI) observations, two powerful processors to correlate the VLBI data obtained globally, and two large radar antennas (46m and 67m) that are used in ionospheric and atmospheric studies.

During the past year, about 200 researchers from US and foreign institutions have used the Observatory instrumentation, including about 40 graduate and undergraduate students as part of their educational programs. In addition, the Observatory is participating in the NSF Research Experiences for Undergraduates program, allowing 15 students from MIT and other area universities to learn about and contribute to our research programs during the summer months. An educational outreach effort has also been successfully initiated to allow Haystack researchers to contribute to pre-college science and mathematics education in the local area schools, and the Observatory has developed a special program for middle school students under the NSF Young Scholars Program. Annually, 25 students participate in this program in addition to several science teachers.

Significant progress was made in the program to upgrade the 37m radio telescope for operation up to 115 GHz (2.6 mm wavelength). The antenna surface deviation was reduced by adjustment from 0.6 mm to 0.35 mm rms, within the goal of 0.2 mm expected to be achieved by the end of 1991. The radio holographic technique used to measure the surface deviations was improved significantly by reducing the observation time required for high resolution mapping to two hours and by eliminating artifacts in the surface maps which had been caused by radome diffraction and spurious multiple reflections. A design for a deformable subreflector was produced by our consultants, Simpson, Gumpertz & Heger, Inc., and a contract for its fabrication was awarded to ESSCO, Concord, MA. This actively controlled deformable subreflector, in addition to a thermal compensation system which is currently being installed, will be used to correct for gravitational and thermal distortions of the antenna surface.

*Boston University, Brandeis University, Brown University, Dartmouth College, Harvard University, Harvard-Smithsonian Center for Astrophysics, MIT, Polytechnic Institute of New York, State University of New at Stony Brook, Tufts University, University of Massachusetts, University of New Hampshire, and Yale University.

A single channel Superconductor-Insulator-Superconductor (SIS) mixer receiver was completed and installed on the antenna to demonstrate the use of the upgraded radio telescope at high frequencies. Molecular spectral lines were successfully observed at both 86 and 115 GHz. This cryogenically cooled receiver is being expanded to two polarization channels. A new spectrometer is almost complete and spectra with 4096 resolution cells have already been obtained on radio sources. This spectrometer will support five signal channels and up to 746 MHz in overall bandwidth with a large selection of available bandwidths and resolutions to meet experimental requirements. As part of the upgrade program, work stations have been provided for data processing and two widely used modern data-reduction packages have been installed on the Haystack computers.

Recent highlights of the single-antenna radio astronomy research include the observation of the galactic center source, G1.6-0.025, at a frequency of 36.2 GHz corresponding to the $4_{-1} - 3_0$ E transition of methanol, which has revealed four new maser sources. The map obtained at this frequency showed very different features from that made at the 12.2 GHz methanol transition at other observatories. Silicon monoxide maser sources have also been detected at 43.12 GHz in late type stars which are both carbon and oxygen rich stars. The variable star R Ceti has shown a good correlation between the optical light curve and the H₂O maser emission at 22 GHz from its envelope. Using Very Long Baseline Interferometry (VLBI) techniques, the nonthermal emission from six pre-Main Sequence T Tauri stars was characterized and seen to vary in morphology and strength on one-hour timescales. Most recently, a second star-forming region, ρ Ophiuchi, was surveyed with VLBI and found to contain a similar population of young nonthermal radio stars. In another application of VLBI to stellar objects, the geometric parallax and proper motion of σ Coronae Borealis were measured to sub-milliarcsecond precision using 5 observations from 1983 to 1991. This was the most accurate distance determination to date for an astronomical object, and placed σ CrB at 22.7 ± 0.1 parsecs.

The accuracy of distance measurements between widely spaced points on the surface of the earth, obtained using VLBI has improved by a factor of ten per decade since the first experiments were performed in the 1960's. The current accuracy of VLBI of better than one centimeter has been achieved through a combination of technology advances, modeling improvements, and analysis innovations. The goal for the 1990's is to approach millimeter accuracy, even on intercontinental baselines. This will require significant improvement in the correction for atmospheric errors, as well as many other factors that become important at the sub-centimeter level, such as antenna structure deformation and local ground movement. The latest VLBI instrumentation improvement was the expansion of the instantaneous frequency range covered by the receivers, which was developed at Haystack for the ongoing geodetic program involving VLBI sites in Massachusetts (Haystack Observatory), New Mexico, California, Alaska, Germany and Hawaii. Data from recent observations have demonstrated that use of radiosonde data to correct for the dry atmosphere and to estimate the wet component of the atmosphere reduces the seasonal variation of baseline lengths. The configuration of the current six station observing program will allow the extension of this type of analysis to three dimensions, and to yield the most sensitive measurements of earth orientation.

As part of its geodetic research program, Haystack Observatory operates the Westford radio telescope for VLBI measurements under a NOAA program. The telescope, consisting of an 18m fully-steerable antenna in an inflatable radome, has been continuously operated for these purposes since 1980. In the last year, the receiver and data acquisition system have undergone substantial upgrades to nearly double the radio frequency bandwidth of observations, which has led to a substantial reduction in systematic errors in the fundamental group-delay measurements. As part of this upgrade, Westford has participated in a series of experiments designed to systematically explore the limits of current precision and accuracy, towards the goal of reaching 1 mm accuracy in global VLBI baseline measurements.

Haystack continued to contribute to the development of the nation's Very Long Baseline Array - (VLBA), which consists of a 10-element array of 25-meter telescopes covering the continental USA, Hawaii and St. Croix, and is under the direction of the National Radio Astronomy Observatory. Haystack has developed the data acquisition systems for the VLBA which included the digitization and high-density recording sub-systems. Haystack has now delivered twenty recorders to the VLBA project and will continue to build the additional recorders needed for the other VLBA sites and VLBA processor. Haystack has also transferred the recorder technology to industry; the recorder headstack is now available from Metrum (formerly Honeywell) and complete VLBA recorders can be obtained from a U.S. company.

In its continuing commitment to push the state-of-the-art in VLBI technology, Haystack has embarked on a major effort to upgrade VLBI data-acquisition and processing technology. With broad support from both the astronomical and geodetic VLBI communities, a program is now in place to extend data-recording rates to more than 1 Gbit/sec continuously, quadrupling present VLBI recording capabilities. Such data rates have already demonstrated in the laboratory, and an engineering development program is now in place to implement this capability into standard field use; we anticipate the first field experiments using this new technology to take place within a year.

During the past year, the Observatory's Atmospheric Sciences program expanded its involvement in the NSF-sponsored CEDAR program, the upper atmosphere component of the US Global Change Research Program. Under this program, an improved optical facility was constructed near the MIT's Wallace Observatory at Haystack to house complementary instrumentation for an expanded program of joint radar-optical observations of upper atmospheric phenomena. Detailed data were acquired during severe magnetic storms in March and April 1990 and again in June 1991 providing an ample data base to investigate upper atmospheric response to intense solar activity. Studies of heavy ion outflow and storm-induced molecular ion dominance at mid-latitudes were completed, and data detailing the response of the lower thermosphere at altitudes of 100-150 km to storm effects were acquired. The absolute amplitude and magnetic aspect angle dependence of intense ionospheric irregularities at E region (100 km) heights was determined, and several studies intercomparing radar, optical, and other ground-based observations detailed energy coupling through the lower thermosphere.

In the past year, instrumentation developed for the atmospheric radar included the operation of a new data acquisition system which provides a capability for improved radar and experiment flexibility using advanced pulse coding techniques. This will allow a greatly improved sensitivity and height resolution for a broad range of ionospheric and thermospheric studies. Software for the optimal analysis of incoherent scatter radar data has also been formulated and demonstrated at Millstone Hill and is being implemented for use with the regular program of ionospheric observations made at the site. High efficiency klystrons were acquired for use with the UHF transmitter, increasing the peak output power by 60%, and the elevation support structure of the 46 m steerable antenna was strengthened in order to improve the survivability of this important structure under severe storm conditions.

JOSEPH E. SALAH

Nuclear Reactor Laboratory

During the past year the Nuclear Reactor Laboratory (NRL) continued its joint interdisciplinary activities with both MIT and non-MIT collaborators: seven MIT academic departments and interdepartmental laboratories, and about 40 other universities, schools, and nonprofit research institutions, such as teaching hospitals. These joint research or teaching and training activities cover a wide spectrum in the life and physical sciences and in engineering, including development of a brain cancer therapy, nuclear engineering, computer control of reactors, training in reactor operations, dose reduction in power reactors, and radiochemistry and trace analysis applied to the health effects of energy use, nutrition, earth and planetary sciences, archeology, and nuclear medicine.

Especially noteworthy developments were the operation of the pressurized water in-pile loop studies aimed at radiation dose and corrosion reduction in light water power reactors, and the continued program in joint research with Tufts–New England Medical Center on the treatment of brain cancer utilizing the boron neutron capture method. The latter project received especially good reviews by an outside review committee and is in the second year of a three-year program. Continued and increased funding is expected.

A major project on in-pile sensors was continued with support from two Japanese companies and from the Electric Power Research Institute (EPRI). The in-pile dose and corrosion studies have evoked increased interest and have provided opportunities for major continuing research efforts. Our research in computer control of reactor power has continued to lead all other similar efforts in the USA.

NEUTRON BEAM TUBE RESEARCH

One of the MIT Research Reactor (MITR) beam tubes is now being utilized for prompt gamma activation analysis. The initial need is for rapid analysis of B-10 in blood and tissue. This is related to our brain cancer project. There are many additional uses for the prompt gamma facility, which we expect to use for elemental analysis on elements difficult to detect by delayed emission gamma activation analysis. A novel inexpensive system was developed at MITR-II for boron assays which rivals the capability of prompt gamma facilities installed at other United States research reactors at an expense an order of magnitude larger. Another beam tube is used, with a specially designed chopper and diffraction system, as a teaching tool for students. Measurements are made of Planck's constant and the reactor's thermal neutron spectrum as well as of various other quantities, such as total cross sections.

RADIOCHEMISTRY AND TRACE ANALYSIS

Professor Frederick A. Frey, Department of Earth, Atmospheric, and Planetary Sciences, and research colleagues utilize the MITR for trace element analyses of geologic materials by neutron activation analysis (NAA). The activation analysis laboratory dedicated to geochemical studies is supervised by Professor Frey and Dr. Pillalamarri Ila and utilized by approximately five MIT graduate students, plus several visiting scientists from foreign countries and other United States universities. During the last year we have expanded our data acquisition capabilities with a significant upgrading of our gamma-ray spectrometry facilities.

A major research effort is our geochemical studies of an upper mantle peridotite body exposed in northern Japan. Our analytical approach utilizes NAA in addition to electron and ion microprobe analyses. This is a collaborative research effort involving researchers from MIT, the Woods Hole Oceanographic Institute, and several universities in Japan.

During 1990-91 Dr. Ilhan Olmez continued a major attempt to increase the utilization of NRL by making its neutron activation analysis facilities and expertise available to industry, other universities, private and governmental laboratories, and hospitals in the area (as described in *The MIT REPORT*, May 1986). Research and/or service-oriented collaborations were established with several MIT research laboratories as well as with other educational and research institutions in addition to those established in previous years, including the University of Michigan, Army Materials Technology Laboratory, and the Environmental Protection Agency (EPA), Triangle Park, North Carolina. Commercial organizations that utilized the NAA expertise of NRL during the past year were GTE, Waltham and Danvers, Massachusetts; Norton Co., Massachusetts; and Physical Sciences Inc., Massachusetts.

Within MIT, research support has been provided to several departments. Impurities in different materials were identified for Professor Otto K. Harling (NRL) and Professor Michael J. Driscoll (Nuclear Engineering) for their in-pile coolant loop project. Impurities that may produce long-lived radioactive isotopes in construction materials were identified for the Plasma Fusion Center. Concentration of chlorine in chemotherapeutic agent loaded biodegradable polymers and sodium in biocompatible and biodegradable polymers were determined for Professor Robert Langer and his group (Chemical and Biochemical Engineering).

Dr. Olmez has been actively engaged in a number of environmental research projects. Financial support has been continued by the Environmental Protection Agency for the investigation of the possibility of using rare earth elements as markers for motor vehicle emissions. A new three-year \$500,000 grant has been obtained from the Empire State Electric Energy Research Corporation (ESEERCO) to study the current toxic metal levels in atmospheric particulate materials and wet deposition in upstate New York. Additional support has been obtained from EPA to allow continued participation in the ongoing Great Lakes project. We are also studying the selenium and zinc concentrations in human serum obtained from healthy subjects and subjects with prostate cancer through a contract from the National Cancer Institute.

A number of other research applications of NAA are summarized in a subsequent section, Reactor Irradiations and Services for Research Groups outside MIT.

NUCLEAR MEDICINE

Neutron capture therapy for cancers is, in principle, a uniquely attractive method of using radiation to destroy tumor cells without significant damage to healthy cells. Boron neutron capture therapy (BNCT) research and testing has a long history at the MITR, going back to the middle 1950s. Currently, interest in this technique has greatly increased due to the apparent successes of Dr. Hiroshi Hatanaka of Japan, who has now used this therapy on approximately 100 people. Dr. Hatanaka became acquainted with BNCT when he worked at MITR during the early trials. At the present time Professor Otto K. Harling has arranged a collaboration with several senior staff from the Tufts–New England Medical Center. Funding for a three-year project has been renewed from the United States Department of Energy (DOE). The \$1.8M grant represents a 50 percent increase over the previous grant. This project completed its fourth year with good progress on all tasks. An outside review committee gave the joint MIT–Tufts New England Medical Center project high grades for performance during its first three years and we expect similar positive results when, as part of the preparation for patient trials, MIT hosts an International Workshop on Neutron Beam Dosimetry. Preparation for the first human clinical trials is currently a central activity of this project.

The MIT Reactor also supports nuclear medicine programs conducted by several hospital and radiopharmaceutical groups outside MIT. A summary of these activities is provided in a following section.

RADIATION HEALTH PHYSICS

The NRL supports a new subdiscipline in the Nuclear Engineering Department (NED), Radiation Health Physics, by providing relevant research opportunities and a specially designed laboratory/demonstration course. This course, 22.09-22.59 Principles of Nuclear Radiation Measurement and Protection, has been reorganized so that it is appropriate for all students in NED. This restructuring has also permitted reduction of NED courses by one course. The Radiation Health Physics program was originated by Professor Otto K. Harling at the NRL and is now under the direction of Professor Jacquelyn C. Yanch, NED, and Francis X. Masse, MIT Radiation Protection Officer. The program is designed to produce graduates who are well educated in nuclear engineering fundamentals as well as in the basics of radiation measurement, management, and protection. Basing this activity at the NRL is particularly appropriate since the MITR provides excellent opportunities to learn many aspects of this subfield in a realistic environment. Support for graduate students has been obtained from the Institute of Nuclear Power Operations, from several nuclear utilities, and several NRL research projects.

COMPUTER CONTROL OF REACTORS

Dr. John A. Bernard of the NRL and Professor David D. Lanning, Nuclear Engineering Department, continued studies on the closed-loop, digital control of nuclear reactors during both steady-state and transient operation. Assistance was received from Professors Allan F. Henry and John E. Meyer (NED). A general set of control principles, based on reactivity constraints and intended for nonlinear conditions, has been deduced and experimentally demonstrated on the MIT Reactor. This approach is unique in that it is based on the general equations of reactor dynamics rather than on measurements of specific response characteristics. This work is currently supported by the United States Department of Energy and by the Sandia National Laboratories (SNL). It has resulted in eight publications during the past year. In addition, five major reports summarizing both the theoretical and experimental work performed in this area have now been issued. The 'reactivity constraint approach' has been licensed by the United States Nuclear Regulatory Commission (NRC) for general use on the 5 MW MIT Research Reactor. Closed-loop control experiments can be performed without *à priori* restrictions on the associated reactivity. The significance of this license approval is that: 1) no other research reactor in the United States has such a broad approval for closed-loop control; and 2) a precedent has been established for our approach regarding such control. This gives the reactivity constraint concept an enormous lead over competing ideas in the United States. Complementing the 'reactivity constraint approach' has been the development of the MIT-SNL Period-Generated Minimum Time Laws, which are closed-form expressions for the time-optimal control of power in reactors subject to restrictions on the minimum allowed period. These permit reactor power to be changed by many orders of magnitude both in a few seconds and without overshoot. These laws are unique in that they are time-optimal and yet both operate in real time and incorporate feedback. Major accomplishments of the project during the past year include the on-line estimation of reactivity during automated reactor startups and the use of inverse kinetics to estimate reactivity during rapid power increases. Research in progress includes: 1) the development of

methodologies for the control of core average temperature; 2) the extension of the non-linear closed-loop control techniques to the operation of various reactor plant components such as steam generators; 3) causal analysis; 4) continued work to improve the robustness of the control laws used for the rapid maneuvering of a reactor's neutronic power; and 5) techniques for the adaptive control of reactor power. Two S.M., one N.E., and one Ph.D. degrees were granted during the past year for research performed on this project. There are currently one N.E. and two Ph.D. theses in progress on topics related to this research. Demonstrations of the technology are available by appointment.

DOSE REDUCTION IN NUCLEAR POWER REACTORS

A major interdisciplinary and interdepartmental research program designed to develop radiation dose reduction technology for the nuclear power industry is in progress. It is currently supported by the Japanese Nuclear Power Engineering Center. Funding at the level of \$620,000 per year is available to support the project. Radiation fields in the primary coolant system of today's light water reactors are undesirable from a health viewpoint and have a significant negative impact on plant capacity factors by impeding maintenance tasks. The principal goal of the project is to reduce the radiation fields to which workers are exposed. Studies of how these fields are built up and methods for minimizing them are being conducted with the aid of small-scale coolant circulation loops installed in the core of the MIT Reactor, designed to simulate (in separate loops) conditions that exist both in pressurized-water reactors and in boiling-water reactors. The formation, transport, and deposition of corrosion products in the coolant is being characterized, and tests are under way to obtain information about optimized water chemistry, surface treatments, and other parameters. Principal investigators are Professor Otto K. Harling (NRL), Professor Emeritus Michael J. Driscoll (NED), and Dr. Gordon E. Kohse (NRL). Others already participating are Dr. Ilhan Olmez, of NRL; members of the MIT Reactor staff; Professors Ronald G. Ballinger and David D. Lanning of NED; Dr. William Lindsay, an expert consultant in the field of reactor coolant corrosion studies; and a growing number of MIT students from the Nuclear Engineering Department. Four utilities – Public Service Electric & Gas, Duke Power, Northeast Utilities, and Boston Edison Co. – have provided additional financial support. These projects utilize the MIT Reactor directly and provide much needed support for experimental research in nuclear engineering. It is expected that two to four graduate students will continue to be involved in this project.

Support for future research in these areas has been obtained for studies with an in-pile loop which simulates boiling water reactor conditions. Sponsors are General Electric, the Electric Power Research Institute (EPRI), Hitachi, and Toshiba.

IRRADIATION-ASSISTED STRESS CORROSION CRACKING

Another project based on the technology in our loop project started in September of 1988 with support from the Electric Power Research Institute and the Tokyo Electric Power Company. This four-year project, supported at the \$500,000/year level, addresses some of the issues associated with irradiation-assisted stress corrosion cracking (IASCC). Extended reactor usage and lifetime prolongations have raised the issue of IASCC in light water power reactors (LWRs) to a high priority. The expertise which we already have in in-pile testing under LWR conditions and our experience in stress corrosion cracking (Professor Ronald G. Ballinger) and nuclear materials testing (Professor Otto K. Harling) were combined to develop a successful proposal for this long-range intellectually stimulating project. An extension of this project for one and one-half years is likely, and a five-year follow-on project is in the planning phase with the sponsors.

SENSOR PROJECT

The Sensor project is a continuing program complementary to the IASCC project described above. It is a two and a half year project funded at approximately \$500,000/year by the Electric Power Research Institute, Hitachi, and Toshiba. Principal investigators are Professor Ronald G. Ballinger and Dr. Gordon E. Kohse, with support from the Dose Reduction and IASCC staff.

Instrumented crack sensors and electrochemical potential sensors will be operated under simulated BWR conditions in the MITR-II core. The primary objective of the research is to demonstrate the effectiveness of hydrogen water chemistry in controlling irradiation-assisted stress corrosion cracking. This research will also contribute to a more general understanding of important IASCC variables: material composition and processing, water chemistry including radiolysis chemistry, and irradiation damage.

REACTOR IRRADIATIONS AND SERVICES FOR RESEARCH GROUPS OUTSIDE MIT

In nuclear medicine, the development and/or continuing production of radioisotopes for use by researchers at hospitals and other universities included: 1) production of Au-198 seeds for Dr. Philip Cobb of the New England Deaconess Hospital for use there for cancer therapy; 2) research activities by Professor Webster S.S. Jee's group at the University of Utah Radiobiology Laboratory using animal models; 3) studies using track etch techniques by Dr. Arant Moothy of the Brookhaven National Laboratory; 4) production of Dy-165 for Dr. Clement B. Sledge of Brigham and Women's Hospital for research studies in the treatment of arthritis; 5) research activities by Professor Fred Bruenger of the University of Utah using solid state fission track detectors to analyze the plutonium content of bones; and 6) investigations by Dr. McDonald Wrenn of the University of Utah using track etching techniques to determine the lower detection limit of uranium in water.

In a number of other areas, also, reactor irradiations and services were performed for research groups outside MIT. Most of these represent new activities, while some are continuations of previous research: 1) spacecraft electronic components were irradiated by Mr. Frank V. Thome of the Sandia National Laboratories in the fast spectrum facility to determine susceptibility to space radiation effects; 2) components for the magnets being considered for the Super Collider were irradiated by Professor James Rohlf of Boston University to assess their capability to withstand radiation; 3) Dr. Mike Kitto, New York Department of Public Health used neutron activation analysis for environmental studies; 4) Drs. Robert F. Anderson and Alan P. Fleer of Woods Hole Oceanographic Institute used irradiation to determine natural actinides and plutonium in marine sediments; 5) Drs. Joseph D. Zuckerman and Marco Chinol of Mt. Sinai Hospital purchased holmium-166 for use in arthritis treatment research; and 6) Professor Jene Golovchenko of Harvard University is using neutron activation analysis as a means of probing the properties of superconducting films. Additional NAA services, including many for research groups outside MIT, are reported above in the section entitled Radiochemistry and Trace Analysis.

Whereas most of the above outside users pay for irradiation services at the reactor, educational institutions needing such services for their own academic or research purposes are assisted in this regard by the USDOE through its "Reactor Sharing Program." A grant to MITNRL reimburses us for the costs of providing irradiation services and facilities to other institutions (including teaching hospitals and middle and high schools). Under this program 1075 students and 241 faculty and staff from over 62 other educational institutions benefited from visits to and use of the MITR during the past year. Popularity of the sharing program continues to grow.

Research utilization of the MITR by other institutions under the Reactor Sharing Program during the past year has included: 1) use by Professors J. Christopher Hepburn and Rudolph Hon of Boston College to activate geological specimens and standards for the NAA of rare earth and other trace elements in studies of the geological development of the northeastern United States; 2) neutron activation analyses of ice cores for the State University of New York, Buffalo; 3) gamma irradiation of plant seeds for several area high school students participating in science fair projects; 4) ongoing research to identify elements other than lead from motor vehicle emissions in collaboration with Professor G. E. Gordon, University of Maryland; 5) food, water, and soil analyses from Rota Island, Forsyth Dental Center; 6) measurements of boron concentration and work on high resolution track etch autoradiography for Professor Robert Zamenhof of Tufts-New England Medical Center; 7) radiation hardness measurements of drift tube detectors being developed for the Superconducting Super Collider program by Professor James Rohlf of Boston University; 8) a study of the effects of oil-well fires in the atmosphere of Kuwait and Saudi Arabia, by Professor J. Spengler, Harvard School of Public Health; 9) the study of elemental depth profiles in sediments by Professor D. Ryan of the University of Lowell; and 10) participation in several special high school student projects.

For education of the general public and students at all levels in local and other New England schools, the reactor staff provides lectures and tours periodically throughout the year. Several local universities incorporated reactor visits and experiments into their regular course curricula, as follows: 1) Northeastern University, Physics Department, Course PHY 1555, 10 students, 2 visits; 2) the University of Massachusetts, Harbor Campus, Professor Martin Posner, Department of Physics, Physics 603, 24 students, 4 visits; and 3) Bates College, Department of Physics, Professor John Smedley, 12 students, 1 visit.

An educational program to familiarize high school science teachers with the scientific, engineering, and medical uses of nuclear research reactors and to involve the teachers in typical applications and experiments, with a special lecture and demonstration by the MIT Radiation Protection Office, is also funded by the USDOE Reactor Sharing Program. Four seminars of four and one-half hours each were held in the spring. The attendance for this year was 56 teachers and 61 students.

MIT RESEARCH REACTOR

The MIT Reactor completed its 33rd year of operation, its 17th since the 1974-75 shutdown for upgrading and overhaul. The reactor normally operates on a Monday through Friday schedule. However, for the past year the reactor operated continuously (seven days per week) during much of the first half of 1991 to support several major experiments related to the dose reduction studies. Also, much low power testing was performed for the neutron capture therapy program. On average, the MIT Reactor was operated 81 hours per week with 62 hours per week at its design power level of 5 MW. Energy output for the MITR-II, as the upgraded reactor is now called, totaled 269,975 megawatt-hours at June 30, 1991. The MITR-I generated 250,445 in the sixteen years from 1958 to 1974.

To summarize briefly the reactor utilization described in more detail above, it was well utilized during the year, although still more experiments and irradiations can be accommodated due to the number and versatility of its many facilities. The reactor, as an integrated whole, continues to be used in a series of experiments designed to demonstrate the feasibility and advantages of reactor control by digital computer. A pressurized loop for a major new interdepartmental project on dose reduction for power reactors is installed in the reactor. A major project on irradiation-assisted stress corrosion cracking, initiated with United States and Japanese support, is progressing. A new large project involving in-pile sensor testing was initiated with

domestic and foreign support. The number of specimen irradiations was 894. There were 98 irradiations in the medical room, most in support of the neutron capture therapy program for the treatment of brain cancer. Theses and publications on research supported by the reactor are running at about 20 and 50 per year, respectively. A total of 1415 people toured the MIT Research Reactor during 1990.

There is an increasing need in the world for irradiation space for neutron transmutation doping of silicon crystals. A project is being initiated for the neutron transmutation doping of single crystal silicon ingots in one of the reactor's horizontal throughports. Thus far, physics and engineering studies have been performed to characterize the neutron beam and to determine the feasibility of uniformly irradiating the ingots with simultaneous translational motion over an interval of several days through the beam port. These measurements and design studies are currently being done by the MITR staff and it is expected that the effort will provide support and research topics for several graduate students. If successful, the result of this project should provide a source of base support to the reactor.

For 1990-1991, Dr. John A. Bernard, Director of Reactor Operations, served as Chairman of the National Organization of Test, Research, and Training Reactors. This organization provides a forum for research reactor managers to discuss regulatory and operational issues. The NRL will host the annual meeting of this organization in October 1991.

DOE continues as the supplier of fuel to university research and training reactors. Babcock and Wilcox (B&W), Lynchburg, Virginia, is the fabricator and is commencing production of another batch of fuel for the MITR-II.

During the past year, in connection with the generic question of such support for university reactors, the National Academy of Sciences-National Research Council (NAS-NRC) has completed a study to assess nuclear engineering education, and this report underlines the importance of research reactors for academic programs in nuclear engineering. Professor Otto K. Harling, NRL Director, continued his efforts on behalf of all United States university reactors to obtain a more rational funding base in the USA for all university research reactors and for nuclear engineering education. These activities have helped to establish a modest budget for university research reactors and a significant level of support for nuclear engineering research. Current efforts are concentrating on increasing the level of funding to levels which will ensure a viable university reactor community.

OTTO K. HARLING

Operations Research Center

The Operations Research Center (ORC), established in 1953 as an interdepartmental graduate degree program, completed its 38th year of continuous operation in 1990-91. The year was marked by the continued success of the Center's educational programs coupled with another significant increase in its research activities and with continued planning for future development.

Highlights of the year included: continuing excellence of our academic programs as reflected by the second largest applicant pool in the history of the ORC; a wide variety of methodological and applied research projects and another increase in the research volume at the ORC; continuing efforts on expanding the Center's outreach; extensive discussions on establishing a Center of Decision Sciences at MIT and progress toward that goal; placement of the Statistics Center under the administrative aegis of the ORC; and a large number of individual distinctions for our students and affiliated faculty and staff. This report provides some details on these 1990-91 activities and reviews briefly the ORC and its educational and research programs.

FACULTY AND STUDENTS

This year the ORC had 30 affiliated faculty and senior staff (28 faculty). Faculty are drawn from the School of Management and the Departments of Electrical Engineering and Computer Science, Civil Engineering, Mathematics, Aeronautics and Astronautics, Mechanical Engineering, Urban Studies and Planning, and Nuclear Engineering. Thomas L. Magnanti, George Eastman Professor of Management Science, and Amedeo R. Odoni, Professor of Aeronautics and Astronautics and of Civil Engineering, continued as the Center's Codirectors. Paulette P. Mosley was the Administrative Officer.

The Operations Research Center offers two interdepartmental graduate degree programs, one leading to a PhD degree in Operations Research and the second leading to a master's degree. During 1990-91, these programs enrolled 53 students--36 PhD candidates and 17 SM candidates. The Center conferred 11 master's degrees and seven PhDs in operations research. Several other PhD theses were in the final stages of completion in the summer of 1991, and the Center will award eight more PhD degrees by September 1991.

For the Fall Term 1990, the ORC expects an incoming class of 15 students, carefully selected from the second largest pool of applicants in the Center's history (about 90 total).

ACADEMIC PROGRAMS

The ORC's academic programs continue to be recognized as ranking among the very best nationally and internationally. Our program, moreover, is repeatedly cited as achieving an excellent balance between applications and methodology.

In view of constraints imposed by our limited financial and space resources, we have determined that the size of our PhD program cannot increase any further over the foreseeable future. We may, however, seek some limited growth, possibly to about 20 enrolled students in the master's degree program. A group of our current students has volunteered to help in developing appropriate informational materials and in publicizing the master's program in selected undergraduate institutions. During the Fall of 1990, these students visited about 10 elite colleges and universities.

Throughout the academic year, the ORC faculty and students have also extensively discussed the structure of the Center's qualifying and general examinations. Based upon the recommendations of a very productive faculty/student committee, the Center instituted several changes in its examination structure for the 1991-92 academic year.

RESEARCH ACTIVITIES

During 1990-91, the volume of research conducted directly through the ORC grew significantly again for the fourth consecutive year. This work, nonetheless, represents but a small fraction of OR-related research carried out throughout the Institute by ORC affiliated faculty and staff. Research activities spanned a wide spectrum of methodological topics and applications and ranged from small, unsponsored projects involving a single faculty supervising a student's thesis to much larger, sponsored programs involving several faculty/staff and students.

Examples of primarily methodological research topics include work on: mathematical programming and combinatorial optimization, including modeling languages and solution methods for integer programming, projective transformation methods for linear programming, and cluster analysis; parallel and distributed computation and algorithms; network flow algorithms; network optimization and network design; probabilistic combinatorial optimization problems - a new class of very interesting probabilistic variations of standard combinatorial optimization problems; facility location in both deterministic and stochastic settings; queueing theory under both static and dynamic conditions; quantifying the equitability of queueing systems; analysis of queueing networks; stochastic processes; classical and Bayesian statistics; and decision analysis and statistical decision theory.

ORC faculty are also currently investigating several major areas of application including: flexible manufacturing systems; financial services; marketing; transportation systems; air traffic control; public services, such as urban emergency systems; criminal justice; safety and risk analysis in air transportation, communication systems, nuclear engineering and epidemiology; remotely controlled queueing systems; and industrial production and transportation logistics.

Several organizations sponsored research projects at the ORC during 1990-91, for example: the National Science Foundation (several projects); the C.S. Draper Laboratory (several projects and Draper Fellowships); MIT's Lincoln Laboratories; the National Institute of Justice, the Department of Transportation; the Office of Naval Research; the Air Force Office of Scientific Research; AT&T; IBM; and the Human Services Research Institute.

OUTREACH PROGRAMS

The ORC and its faculty and staff, in their effort to serve the professional community at large, regularly undertake a number of outreach activities.

For instance, the ORC offers professional courses during the Summer Session. It offered one such program, "Airport Systems: Strategic Planning and Detailed Design," during the summer of 1990 and 1991.

The ORC has also continued the "OR Clinics" program under which the Center arranges half-day workshops focused on a particular problem presented by representatives of a company. One clinic took place this year, for Sea Land, Incorporated. We are pleased that this program provides a useful service to our colleagues in industry and at the same time gives participating faculty and graduate students added insights into problems currently faced by major companies.

In April 1991, ORC faculty, in cooperation with the Center for Transportation Studies, presented 1991 a one-day symposium on "Applications of Networks." Four MIT, one Princeton, and one University of Montreal faculty and a researcher from Roadnet Technologies gave presentations on topics that reflect the cutting edge of current research on applications and methodology. Approximately 30 representatives from business and industry attended.

The ORC Seminar Series was privileged to have many distinguished speakers from business and industry as well as from academia this year. Among the many operations research professionals who made presentations were Y.C. Ho, Harvard University; Marshall Fisher, The Wharton School; Thomas C. Cook,

American Airlines Decision Technologies; Roman Polyak, IBM Research Center; Margaret Brandeau, Stanford University; Erhan Cinlar and Warren B. Powell, Princeton University; Paul Zipkin, Columbia University; and Ralph Disney, Texas A&M University.

DECISION SCIENCES CENTER

The possibility of establishing a Center for Decision Sciences at MIT continued to dominate any discussion of long-range planning for the ORC. The Center for Decision Sciences (CDS) would bring together a number of currently existing centers and laboratories, including the ORC. A proposal submitted to the MIT Administration provides a vision of CDS that would include: a three-track master's and Ph.D. program in Operations Research, in Statistics, and in Decision Processes; a major research program centered on the decision sciences and on the impact of technologies fostered by the era of the information revolution; a computational laboratory; a learning laboratory; a large industrial affiliates program; and a visitors and senior fellowships program.

Consultations among faculty from various parts of MIT, as well as with the MIT Administration, continued during 1990-91 on the subject of CDS and significant convergence of views had been achieved by the end of the year. The placement of the Statistics Center under the ORC's administration (a change which took place in July 1990) has provided additional impetus toward the formation of CDS. It is expected that, during the coming academic year 1991-92, the Institute will make critical decisions regarding the future of this important initiative.

SOME INDIVIDUAL ACCOMPLISHMENTS

A number of ORC-affiliated faculty and students received noteworthy distinctions during 1990-91

Professor Thomas L. Magnanti, a Codirector of the ORC, was elected to the National Academy of Engineering and cited for his O.R. contributions namely for leadership in operations research including fundamental contributions to optimal design of communication and telecommunication networks, and in education in manufacturing.

Professor Dimitris J. Bertsimas (Sloan School of Management) won a Presidential Young Investigator (PYI) Award from the National Science Foundation and joined three other previous winners (Professors James B. Orlin, John N. Tsitsiklis and Lawrence M. Wein) on our faculty.

Four of our faculty were recognized for their outstanding teaching. Professor Alvin W. Drake (Electrical Engineering and Computer Science) was the first winner of the School of Engineering Amar G. Bose Award for excellence in teaching his Applied Probability subject over a period of more than 25 years. Professor Arnold I. Barnett and Robert M. Freund were the co-recipients of this year's Graduate Student Council Teaching Award for the Sloan School of Management. Professor Amedeo R. Odoni, a Codirector of the ORC, was a co-recipient of the Federal Aviation Administration's 1990 Award for Excellence in Aviation Education.

Professors Arnold I. Barnett, Gabriel R. Bitran, Alvin W. Drake, Robert M. Freund, Stephen C. Graves, Daniel J. Kleitman, Richard C. Larson, Thomas L. Magnanti, Amedeo R. Odoni, and James B. Orlin continued serving in important editorial capacities of the top professional journals in OR and management science.

THOMAS L. MAGNANTI
AMEDEO R. ODONI
Codirectors

Plasma Fusion Center

The primary objective of the Plasma Fusion Center is to develop a basic understanding of the behavior of plasmas, and to exploit that knowledge by developing useful applications involving the plasma medium. The most important potential application is the development of fusion power; however, as can be appreciated by scanning the research highlights presented below, applications involving this ubiquitous state of matter are numerous and diverse. This richness of a field which is so wonderfully deep and intellectually challenging, and yet possesses so many fascinating applications, makes the Plasma Fusion Center a very exciting place to carry out research.

The Plasma Fusion Center (PFC) is recognized as one of the leading university research laboratories in the physics and engineering aspects of magnetic confinement fusion and plasma research. Its research programs produce significant results on several fronts: (a) the basic physics of energetic plasmas (plasma theory, RF heating, nonneutral plasmas and coherent EM wave generation, development of high-temperature plasma diagnostics, and basic plasma experiments on the Versator II and Versatile Toroidal Facility tokamaks), (b) experimental confinement research on the Alcator C-MOD tokamak (investigations of the stability, heating, and transport properties of plasmas at high densities, temperatures and magnetic fields), and similar collaborative efforts on other tokamaks in the United States and Europe, and (c) a broad program of technology and engineering development (e.g., magnet systems, superconducting materials, fusion environmental and safety studies, advanced millimeter-wave sources, system studies of fusion reactors including operational and technological requirements, and plasma waste-treatment systems).

The Plasma Fusion Center technical programs are supported principally by the Department of Energy's Office of Fusion Energy. There are approximately 320 personnel associated with PFC research activities. These include: 34 faculty and senior academic staff, 77 graduate students and 36 undergraduate students, with participating faculty and students from Aeronautics and Astronautics, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics; 83 research scientists and engineers and 24 visiting scientists; 32 technical support personnel; and 35 administrative and support staff.

During the past year, we have continued to strengthen and expand our K-12 educational outreach program. Our goal is to convey to students in the K-12 system a notion of what plasmas are, how they behave and the role they play in the production of fusion energy. A secondary but perhaps more important goal is to impart a sense of what scientists and engineers do and the rewards that come with discovering the laws of nature and putting them to practical use. Our efforts have reached over one thousand students and teachers in the last year, and have included two open houses, one each for high school and middle school students and teachers, special visits and tours by classes from over fifty schools, and visits on the part of faculty, graduate students and staff to several schools. In addition, a member of our research staff, George Johnston, has taught a course on nonlinear dynamics (chaos) to high school students from Wyoming, Montana, Colorado and California by means of electronic communication. This experience indicates that on-line teaching can be a very effective way of providing science instruction, especially to K-12 teachers who have generally had little or no science education. We plan to continue to explore and develop the potential of this approach during the coming year, augmenting on-line instruction with occasional personal contact and assistance in performing simple demonstrations.

In last year's report, we called attention to the declining budgets which have characterized funding for fusion, as well as other advanced energy technologies, for the past decade. Funding limitations have forced a premature narrowing of the options available to the magnetic fusion program with most of the effort now focussed on the development of the tokamak configuration. On the positive side, both the report of the Department of Energy's Fusion Policy Advisory Committee (FPAC) and the National Energy Strategy (NES) are upbeat with regard to the potential of fusion and its role in a long term energy policy. Thus, although all federally funded research budgets are highly constrained by efforts to stabilize the budget deficit, the present outlook for fusion development is far more hopeful than it has been in recent years. The Secretary of Energy's personal interest and attention to the program has been a key factor in creating this more favorable climate.

Both the FPAC report and the NES call for the fusion program to evolve from a broadly based research effort to a more focussed energy development program. Three new facilities are identified as essential to the process: a burning plasma experiment, which explores the physics behavior of plasmas which are energetically self-sustained, or nearly so, by fusion reaction products; an engineering test reactor which produces burning plasmas with reactor relevant technologies and develops key nuclear components; and a demonstration power reactor which produces substantial quantities of net electrical power. The rough time-frames for operation of these devices are the years 2000, 2010 and 2025, respectively. As presently envisioned, the burning plasma experiment or BPX will be a nationally based project built at the Princeton Plasma Physics Laboratory, while the engineering test reactor will be constructed by a four-way international partnership involving the United States, the Soviet Union, the European Community and Japan. This device is called the International Thermonuclear Experimental Reactor (ITER), and the planning process is now moving from a conceptual design phase to an engineering design period which will include a substantial (~ \$1 billion) R & D effort.

Plasma Fusion Center programs are strongly coupled to the design of both the BPX and ITER devices and will ultimately support their operation. Alcator C-MOD, our new high-field tokamak scheduled for initial operation toward the end of this summer, is in many ways prototypical of BPX as it has the same design field (9 Tesla) and shape (aspect ratio and elongation). The physics program will address critical issues for BPX associated with energy and particle transport, RF heating, impurity control, and heat removal. Overall performance is expected to compare favorably with the largest tokamaks now operating in the world, and should this performance be realized the prospects for achieving near-ignition conditions in BPX will be excellent.

The physics program for Alcator C-MOD is also highly relevant to ITER and the addition of RF current drive in a later phase would further enhance its value to the ITER program. Beyond Alcator C-MOD, PFC programs support ITER in critical technology areas, including superconducting magnetics and development of millimeter wave RF sources suitable for heating and driving current near the electron gyrofrequency. In the magnetics area, D. Bruce Montgomery, head of the Fusion Engineering and Technology Division, has been named leader of the US ITER magnetics effort. This assures the PFC a position of prominence in what is envisioned to be an extensive program of superconducting magnet development leading to construction of magnets at a scale and performance level well beyond that of present-day superconducting magnet experience.

With this as background, we turn our attention to highlights of the past year's research. The remainder of the report is organized to correspond to the five PFC Divisions: Toroidal Confinement, Physics Research, Fusion Technology and Engineering, Fusion Systems, and Coherent Electromagnetic Wave Generation.

TOROIDAL CONFINEMENT DIVISION

The toroidal confinement division, led by Ian Hutchinson, consists primarily of the Alcator group, which is carrying out experimental research on high-field, high-performance tokamaks. The new device, Alcator C-Mod, which has been under construction since 1987, is nearing completion and will come into operation in the fall of 1991. Alcator C-MOD is the third generation of high-field tokamak devices built at MIT, beginning with Alcator A whose construction was initiated in 1969.

Alcator C-Mod is a flexible and cost-effective confinement experiment with the major aim of supporting the Burning Plasma Experiment under design at Princeton Plasma Physics Laboratory. It will also explore new regimes of plasma operation close to those of fusion ignition, so as to improve the plasma performance of the tokamak and establish a physics understanding of the magneto-hydrodynamic (MHD) equilibrium and stability, transport, wave heating, and edge plasma properties.

The activities within this Division are organized into four principal groups: Plasmas (Steve Wolfe), Experiments (Earl Marmor), RF Heating (Miklos Porkolab) and Operations (David Gwinn). Highlights of the recent technical progress made by each of these groups are presented below.

Plasma Group

This group focuses on the areas of transport (Martin Greenwald) and MHD (Robert Granetz) physics, and developing optimized control procedures for tokamak operation.

The substantial elongation and triangularity of Alcator C-MOD will permit tests of MHD equilibrium and stability physics in previously unexplored regimes, and address issues of interdependence of transport and MHD. The thick conducting structure of the C-MOD vacuum vessel is prototypical of reactor construction, and presents unique problems in plasma startup, control, and disruption characteristics.

The magnetics diagnostics system is fully installed and calibration is complete. Associated interpretation computer codes required for initial plasma operation are nearly finalized. Studies of electromagnetic requirements for breakdown and plasma initiation have been carried out and satisfactory scenarios for this aspect of machine operation identified.

A powerful new software package, MDSplus, for acquisition, archiving, and manipulation of experimental data has been developed in collaboration with Istituto Gas Ionizzati (IGI) (Padova, Italy) and Los Alamos National Laboratory. The first version of MDSplus has been released, and is now being applied to the development and testing of diagnostic and control subsystems for Alcator C-MOD. The C-MOD VAX-cluster is operational with over a dozen nodes in place. Timing modules and the initial version of software support for fast sequencing have been procured.

A novel digital-analog hybrid control system has been developed in collaboration with the CRPP of Ecole Polytechnique Federale de Lausanne (Suisse) and will be first implemented on Alcator C-MOD. The Hybrid Computer hardware is now on site and has passed its initial tests. The operator interface software, which allows the physics operator to configure the control system, specify control waveforms, compute and download control laws to the Hybrid, is in development. Several algorithms for generating the plasma control matrices have been developed and tested against computed equilibria.

Transport studies on this new tokamak, which features poloidal divertors, strong shaping, and intense radio-frequency heating, will be key in the development of the predictive capability required to characterize the confinement behavior of ignited and reactor-like tokamak devices. Key elements of the research include profile and shaping effects, physics of "enhanced confinement" regimes, anomalous ion transport, problems of transport in the presence of auxiliary heating, and scaling of transport with size and aspect ratio. A pellet injector has been developed, which will fuel the plasma with frozen pellets of hydrogen injected at about 1 km/s. It will play an important role in the first phase of transport physics experiments.

Experiments Group

This group focuses on studies of edge plasma physics (Bruce Lipschultz) advanced plasma diagnostics (James Irby) and other experimental techniques for understanding and improving plasma performance.

Much of the effort over the last 4 years among the physics staff in the Alcator group has been devoted to the design and construction of a state-of-the-art diagnostic set for the Alcator C-MOD tokamak. As first operation of the tokamak approaches, the majority of the diagnostic systems are nearing completion. Among the most advanced and innovative diagnostics of the plasma core are: Multi-pulse Thomson scattering for multi-time (50 Hz) and multi-spatial (2-D) measurement of the electron density and temperature; 6 frequency reflectometer (electron density profile); 5 channel high resolution curved crystal soft x-ray spectrometer (impurity emission spectrum and ion temperature); in-vacuum magnetic coils and flux loops (plasma current position and magnetic instabilities); 200 channel soft x-ray imaging array for tomography; a charge-exchange spectrometer for measurement of the neutral energy spectrum (ion temperature).

Extensive work in the edge plasma area has been devoted to the construction of the plasma facing components: divertor and limiter tiles made of molybdenum. The majority are now installed in the tokamak. Many edge-plasma diagnostics have also been designed. The emphasis is on the interaction of the plasma with the surrounding material surfaces. Measurements of the local electron density and temperature are made directly with high-speed reciprocating Langmuir probes. The relative amount and charge state of impurities in the edge plasma will be determined by a charge/mass spectrometer and the temperature of 'first-wall' surfaces will be determined by an infra-red imaging system. The flow of impurities in the edge plasma will be investigated by injecting gases at selected spatial points and following the movement of the resultant ions with cameras suitably filtered for the impurity ions under investigation.

Collaborative impurity (Li and C) pellet experiments, which began at TFTR (Princeton Plasma Physics Laboratory) in 1989, and are expected to continue at least through 1991, have produced several important results. The most significant of these are: 1) improvements in TFTR supershots after wall-conditioning by Li pellet injection, leading to record high fusion reaction rates; 2) accurate measurements of the pitch angle profiles of the internal magnetic field using the polarization angles of line emission from Li^+ in the pellet ablation cloud; and 3) initial measurements of pitch angle profiles using the tilt of the Li^+ emission region of the ablation cloud which is stretched out along the field lines.

RF Heating Group

This group has responsibility for the implementation and analysis of plasma heating using radio frequency (RF) power. Key physicists are Yuichi Takase and Stephen Golovato.

RF heating requires high power RF to be generated, transmitted to the tokamak, launched into the plasma, and absorbed by it. Successful RF heating will bring the C-MOD plasma to temperatures of 4-8 keV, well in excess of those obtainable by Ohmic heating alone.

The present RF transmitters operate at a frequency of 80 MHz, and consist of four 2.0 MW RF sources. Two of these transmitters are being upgraded to long pulse operation (1 sec pulse length), and installed in the Nabisco Laboratory. This upgrade will be completed and the transmitters interfaced with the C-MOD control system in the fall of 1991. The first antenna for coupling the power to the plasma has been fabricated and is ready for installation. A second antenna, capable of more flexible phasing and probably higher power handling, is under construction.

A frequency of 80 MHz corresponds to the gyrofrequency of helium ions at the center of the plasma column at 8.1 Tesla magnetic field. The power is transferred to the resonant ions which then thermalize by collisions with the bulk plasma particles, thereby "heating" the plasma toward thermonuclear temperatures. We are also considering an upgrade of our transmitters to tunable units with frequencies in the range of 70-140 MHz. This would allow heating of hydrogen ions in the magnetic field range of 4.5-9.0 Tesla. At present the funds have not been provided yet for such an upgrade (estimated to be 5-6 million dollars). A favorable outcome of these experiments is central to the success of the Burning Plasma Experiment, where the effectiveness of RF heating to ignition at high densities and magnetic fields is one of the key issues.

Capability to do sophisticated full-wave modelling of the wave propagation and absorption processes within the plasma has been developed (Paul Bonoli), in collaboration with scientists from the Max Planck Institute at Garching in Germany. These and similar code calculations are being coupled with transport simulations to provide complete modelling of the heating experiments.

Operations Group

This group is responsible for the successful completion of the major fabrication of the device and thereafter for the operation, maintenance and development of the major tokamak systems. Stephen Fairfax provides additional leadership in this area as project engineer and deputy project manager. Frank Silva heads the tokamak operations crew.

The construction was started in 1987. Major activities included site development, fabrication of the tokamak, upgrade of the 225 MVA alternator, and procurement and installation of power conversion and radio frequency power equipment. Commissioning of the subsystems is underway and integrated systems testing will begin in August, 1991.

The experimental cell was constructed with 1.6 meter concrete shielding walls; in addition, a 0.6 meter thick concrete 'igloo' shield was constructed to provide additional neutron shielding for the tokamak. The tokamak is being assembled in the center of the cell, and the power conversion equipment is located in an adjacent power room. A total of nearly 600 MVA of power conversion capacity has been installed. The prime power for the experiment comes from the 225 MVA alternator which was used for Alcator C. The energy storage is being quadrupled by the installation of a 35 ton flywheel, resulting in a total stored energy of 2000 MJ. The flywheel

is scheduled for delivery in September, 1991. Total expenditures since 1987 for the site, tokamak and associated power systems are approximately \$30M.

Work is now underway on the development and implementation of the various procedures which are required for the safe and efficient operation of the experiment. Because of the large stored energy, high power electrical systems, and neutron radiation associated with operation of the experiment, a rigorous safety program has been implemented (Catherine Fiore), requiring formal review and approval of all safety related activities and the procedures for carrying out those activities.

FUSION TECHNOLOGY AND ENGINEERING DIVISION

The Plasma Fusion Center's Fusion Technology and Engineering Division, headed by Bruce Montgomery, provides engineering analysis for advanced projects centered around magnetic systems, and carries out research and development for those applications. The focus of the work is drawn from the fusion program, but in 1990-1991, about 30 percent of the activities were non-fusion applications.

The largest fusion activity in 1990-1991 (45 percent) was design and development of the poloidal field (PF) system for the Burning Plasma Experiment. The PF design effort is led by Richard Thome. Development of advanced high-strength high-conductivity materials are a major part of that program, with members of the Mechanical Engineering and Materials Science Departments providing significant support. During the past year, Bruce Montgomery continued to serve as head of the tokamak systems design, a position which he has reluctantly relinquished in order to take on a key responsibility in the ITER magnetics area.

The second largest fusion activity (25 percent) was design and development of magnetic systems for the ITER device, an international design project which will hopefully lead to construction of a prototype fusion test reactor early in the next century. A particular highlight was the completion of a major test article for the ITER magnetic system. A two-meter outer diameter superconducting magnet, built as a prototype for the ITER transformer was completed in 1990 utilizing advanced niobium-tin superconductors and an internal cooling strategy invented at MIT in the 1980's. Members of the Department of Materials Science have been instrumental in developing the new alloys used in the conductor structural support. The coil was tested in Japan as part of an international collaboration, using facilities unavailable elsewhere in the world. The project was led by Mitchell Hoenig (deceased) and Mike Steeves.

Non-fusion applications in 1990-1991 (30 percent of the division effort) have been dominated by work on the Superconducting Super Collider. MIT proposed a novel method of stabilizing the superconducting interconnect bus for the 8000 ring magnets, and were commissioned to carry out the detailed design, R&D and delivery of the first thirty units needed for near-term magnet tests. SSC work has also been carried out jointly with the Laboratory of Nuclear Science (LNS) for the SSC large detectors, including design work on magnetics and experimental work on liquid xenon. Marcel Gaudreau and Jim Sullivan are leading the PFC efforts in the collaboration with LNS on the xenon detector.

One of the growth areas that we anticipate in 1992 is in the area of magnetically levitated high-speed vehicles. Work will be carried out in conjunction with the Electrical Engineering Department, the Lincoln Laboratory, and the Center for Transportation Studies.

PHYSICS RESEARCH DIVISION

The primary objective of the Plasma Fusion Center's Physics Research Division, headed by Miklos Porkolab, is to develop a basic experimental and theoretical understanding of plasma properties. Since Miklos Porkolab has replaced Ronald Davidson in 1991 as division head, some reorganization has been carried out. Present physics research activities in the reorganized division include the following: experimental research on the Versator II tokamak (Miklos Porkolab and Ronald Parker); the Versatile Toroidal Facility, or VTF (Ronald Parker, acting head); collaboration on the PBX-M tokamak at the Princeton Plasma Physics Laboratory and the JET tokamak at Culham, England (Stanley Luckhardt, Jay Kesner and Paul Woskov); fusion theory and computations (Abraham Bers, Bruno Coppi, Thomas Dupree, Jeffrey Freidberg, Jay Kesner, Kim Molvig, Jesus Ramos, and Dieter Sigmar); theoretical research on coherent radiation sources and accelerators (Jonathan Wurtele); RF interactions and modelling (Paul Bonoli, Ron Englade and Miklos Porkolab); ionospheric plasma research (Min-Chang Lee); X-ray, γ -ray and Fusion Products Diagnostics (Richard Petrasso); small scale

turbulence and chaos (Paul Linsay and George Johnston). Highlights of progress made during the past year in selected physics research areas are summarized below.

Versator II Research Program

Versator-II is a medium-sized research tokamak (the oldest in the US, with major radius $R = 40.5$ cm, minor radius $a = 13$ cm, toroidal magnetic field $B = 1.5$ T) with primary emphasis on basic investigations of radio-frequency (RF) plasma interactions, including heating and non-inductive current drive, studies of plasma stability and development of novel diagnostics. Experiments on Versator II during the past year have focused on completing three Ph.D. thesis projects, including studies of: (a) Launching the "fast-branch" of lower hybrid waves at a frequency of $f=800$ MHz using innovative dielectric-loaded waveguide array couplers, and observing the "synergistic" interaction of such waves with a suprathreshold electron distribution created by a "slow" lower hybrid wave at a frequency of $f = 2.45$ GHz; (b) electron cyclotron heating (ECRH) and plasma startup experiments using a 200 kW gyrotron microwave source at a frequency of 28 GHz, and study of the synergistic interaction of ECRH with a suprathreshold electron distribution, formed by a slow lower hybrid wave at 2.45 GHz; (c) studies of plasmas with high values of poloidal beta using a novel X-ray diagnostic for measuring the current profile, and a magnetic loop array for measuring the fluctuation spectrum.

The Versator II facility was also used in a number of collaborative experiments which included (a) studies of electron cyclotron resonance (ECR) plasma discharge cleaning in collaboration with Alcator C-MOD researchers; (b) antenna development experiments in the ion cyclotron range of frequencies (ICRF) also in collaboration with Alcator C-MOD researchers; (c) development of a new diagnostic, utilizing electron cyclotron transmission measurement to probe non-Maxwellian electron populations, in collaboration with University of Maryland scientists, and (d) studies of plasma edge turbulence using a reciprocating Langmuir probe apparatus, in collaboration with the University of Texas. Additional collaborations included material testing with industrial partners (SPIRE and AZTEC) who have obtained SBIR contracts to develop new and novel insulating coatings (boron-nitride and diamond) for plasma-facing components in tokamak plasmas, with potential reactor applications. If successful, such coatings may also be used in Alcator C-MOD for impurity control. Versator personnel have also been involved in collaborations with off-campus facilities, such as the DIII-D tokamak at General Atomics, San Diego, where one of our students is carrying out a thesis research project on testing a new diagnostic, namely phase contrast interferometry, for the study of plasma turbulence.

Versatile Toroidal Facility (VTF)

VTF is a new toroidal facility which has been built mainly by UROP students under the direction of Marcel Gaudreau in the Nabisco Laboratory. The main machine parameters are $R = 93$ cm, $a = 27$ cm, elongation 1 - 1.6 and toroidal magnetic field $B = 1.0 - 1.6$ Tesla. The machine utilizes the old ISX-B magnets from Oak Ridge National Laboratory. VTF is a flexible toroidal facility with a new vacuum chamber with the capability of operating with pulsed tokamak discharges of up to 2 s duration. Present experiments include plasma formation with a 3 kW ECR plasma source on loan from Alcator C-MOD. The ECR plasmas produced in this manner provide low temperature plasmas which are ideally suited for ionospheric plasma physics experiments. We are presently exploring means of obtaining funding from DOE for an upgraded operation of this device. One promising area of research that has been identified includes studies of advanced divertor concepts. VTF would be ideal for such studies since it is highly flexible, and is accessible for quick modifications due to its many large ports which permit manned access.

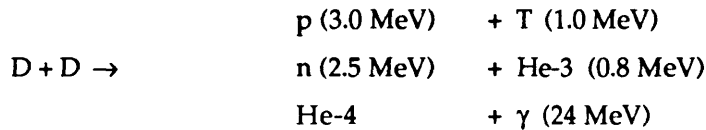
Collaboration with the PBX-M and JET Tokamaks

In the past year a new research group was formed at the PFC with the aim of investigating improved operating regimes in tokamaks. In particular, the MIT developed technique of RF current drive is being exploited for the purpose of controlling and optimizing the current profile in tokamaks. One application of current profile control is to attain plasma beta values in the so-called second stability region. Beta is the ratio of the plasma pressure to the pressure of the magnetic field that confines the plasma. The plasma pressure is the product of the temperature and the density, two quantities which directly determine the fusion reaction rate in hot plasmas. In previous tokamak experiments the plasma beta values have been limited by pressure-gradient-driven magneto-hydrodynamic (MHD) instabilities. However, recent theoretical work by J.J. Ramos and J. Kesner has predicted that tokamaks with properly optimized current profiles can be immune to the MHD instabilities, leading to greatly improved tokamak performance. The experimental work to produce and measure such optimized configurations requires access to large tokamaks with significant auxiliary heating

power and rf current drive capability, so in the past year we have initiated collaborations with the European Communities fusion research facility, JET, and with the Princeton Plasma Physics Laboratory (PPPL). The collaborations are developing successfully and experiments are being carried out at present on the JET tokamak ($R_0=3\text{m}$, $a=1\text{m}$, $I=7\text{MA}$, $B=3.5\text{T}$, $P_{\text{heating}}=40\text{MW}$), and will begin in the fall on the PBX-M tokamak ($R_0=1.6\text{m}$, $a=0.3\text{m}$, $I=0.5\text{MA}$, $B=1.8\text{T}$, $P_{\text{heating}}=7\text{MW}$) at PPPL.

X-Rays, γ -Rays and Fusion Products Diagnostics

One of the principal activities of the X-ray, γ -ray and Fusion Products Diagnostics Group has been the renovation and refurbishment of a Cockcroft-Walton linear accelerator during the past year. The Cockcroft-Walton accelerates various ions (typically H, D, or He-3) into various targets in order to either generate fusion products or intense monochromatic X-rays. For example, when D is accelerated into a deuterated titanium target, the following reactions of interest occur:



In collaboration with physicists from the MIT Center for Space Research, the group is presently irradiating CCD chips with 3.0 MeV photons from the first branch in order to assess the expected proton damage resulting from the passage of CCD's through the South Atlantic Anomaly (in a satellite X-ray telescope). In addition, this group is currently developing plasma diagnostics that are based on the detection of either the charged fusion products or γ -rays (e.g., the last branch above). Using the same accelerator, a PIXE X-ray source (Particle Induced X-ray Emission) was recently developed. It has the distinct advantage over standard electron-beam X-ray sources in that it has no bremsstrahlung background to obscure the characteristic line emissions. This source would be used to test and characterize a wide variety of novel X-ray detectors, such as diamond photoconductors.

Fusion Theory, Computations and Thermonuclear Plasmas

The fusion theory and computations group is continuing its shift of emphasis from linear instabilities to nonlinear plasma models and turbulence. To keep in step with large scale computing trends, a SUN workstation coupled to a SKY station application accelerator capable of 60 MFLOPS has been acquired for immediate use in ongoing Hamiltonian guiding center Monte Carlo simulations of fusion born alpha particles. These particles may be scattered by Alfvén wave turbulence in burning plasmas, with a resulting deteriorated confinement. This area continues to be one of our main strengths, and it is exerting influence on the understanding and design of planned burning plasma experiments, such as BPX and ITER. Related to this topic is another computational simulation project, modelling the self-consistent alpha-particle and electromagnetic field evolution of a fusion plasma. Analytic expertise has been strengthened to accompany these numerical efforts, including the discovery of a hitherto overlooked ion Landau damping mechanism which may well affect Alfvén turbulence.

In the area of plasma energy confinement analysis, our collaboration with the Tokamak Fusion Test Reactor (TFTR) experiment at Princeton Plasma Physics Laboratory has led to a new insight into the collective oscillation mechanisms responsible for the plasma edge transport at elevated levels of plasma pressure. Our group also continues to participate actively in the design activities of the ITER and BPX projects. The historically pioneering idea of achieving ignition in a high magnetic field and high density tokamak, such as Ignitor, continues to exert a strong influence on the evolving design of the Burning Plasma Experiment (BPX) at Princeton.

Theory of Coherent Radiation Generation and Accelerators

This group conducts theoretical research on the physics of charged particle beam radiation sources and advanced accelerator concepts. The group also provides theory support to the Coherent Electromagnetic Wave Generation Division. We have developed, over the last year, a multiple waveguide mode theory of the cyclotron resonance maser. This nonlinear model, which includes self-fields, efficiency enhancement and harmonics, has been implemented numerically and agrees with experimental results. Among the predictions made by the simulation, and yet to be confirmed experimentally, is that mode-locking occurs in the nonlinear regime. Further comparisons with experiment are ongoing. Significant progress has been made in reducing the

RF phase sensitivity to jitter in the two-beam accelerator, which was first realized to be a severe constraint over five years ago. This work included the invention of a new radiation source, a standing-wave free electron laser. A numerical and analytical analysis of longitudinal and transverse coupled bunch storage ring instabilities, the first to allow for an arbitrary charge in each particle bunch, has been performed and used to study the expected performance of the Bates South Hall Ring.

RF Interactions and Modelling

This is a new group and is under the leadership of Paul Bonoli of the Plasma Fusion center. Other contributors include Ron Englade and Miklos Porkolab and one graduate student. The group is involved in carrying out theoretical and numerical work specifically related to Radio-Frequency heating and current drive projects in BPX and ITER (national and international projects). We also expect a strong interaction with the Alcator C-MOD RF heating program.

Ionospheric Plasma Research

Under the sponsorship of NSF, NASA and the Air Force Phillips Laboratory (AFPL), several experiments on ionospheric plasma heating by high power radio waves were conducted at Arecibo, Puerto Rico and Fromso, Norway to investigate the RF induced plasma turbulence and the nonlinear electromagnetic wave propagation and interaction in turbulent magnetoplasmas. Diagnoses of the RF interaction with ionospheric plasmas were carried out by in-situ measurements with satellites and by radio and optical measurements with ground-based radars and all-sky imagers. Some experimental results have corroborated our proposed theories regarding the nonlinear scattering of VLF waves off plasma turbulence and the generation of intense ion acoustic turbulence by the nonlinear coupling of enhanced Langmuir waves in the ionosphere. A new, flexible high-resolution data acquisition system is currently under development at PFC for the investigation of nonlinear ionospheric plasma processes such as the evolution of microscopic plasma instabilities with incoherent backscatter radars.

Laboratory simulation of ionospheric plasma heating and induced nonlinear effects has been initiated with the newly constructed Versatile Toroidal Facility (VTF) at the Plasma Fusion Center Nabisco Laboratory. The preliminary experiments, supported by the Air Force office of Scientific Research (AFOSR) and NASA, are aimed at studying the anomalous absorption of microwaves in turbulent magnetoplasmas. Research effort has been centered on the turbulent scattering and the nonlinear mode conversion processes. Laboratory experiments are also planned for the investigation of the diffuse plasma resonances observed in the ionosphere and magnetosphere. The VTF plasma device can generate a large volume of plasma immersed in a toroidal magnetic field, which is ideal for simulating the space plasma environment.

Small Scale Turbulence and Chaos

A new research project on small scale turbulence and chaos in plasmas has been initiated. The purpose of this program is to identify conditions under which plasmas and plasma substructures behave as chaotic nonlinear systems and exploit this to increase the understanding of plasma dynamics. As a first step, we have tried to identify chaotic behavior in plasma time series by using the technique of forecasting. In principle, a chaotic time series is predictable, at least a short time into the future, unlike a random time series which is not. By comparing predictions made with nonlinear forecasts with predictions using linear autoregression (which is known to work as well as possible on correlated random noise), it is possible to distinguish between chaos and random noise. Preliminary analysis of data from the European tokamak JET sent by collaborators from the Netherlands indicates that there are plasma conditions which are chaotic. These time series might have been thought random using less sophisticated techniques.

An understanding of many coupled nonlinear oscillators is important for models of pattern formation and turbulence in fluids such as plasmas. Experiment and theory in this area are under way. Much theoretical work has been devoted to understanding the results of experiments with 15 coupled electronic oscillators. We now have a good understanding of the number of different final states and their properties. The transient behavior that precedes phase locking has also been studied and is partially understood. Some new phenomena have been uncovered here that have never been observed before.

FUSION SYSTEMS DIVISION

The Fusion Systems Division, headed by Daniel Cohn, investigates a variety of aspects of fusion reactor design, develops new applications of plasma technology, such as plasma treatment of waste, and develops new

diagnostic technology. Current research areas include: concepts for long pulse burning plasma experiments (Leslie Bromberg, Daniel Cohn); pilot plant design study (Daniel Cohn, Leslie Bromberg); commercial reactor design studies (Leslie Bromberg); safety and environmental studies (Mujid Kazimi); and millimeter-wave and infrared diagnostic development (Paul Woskov).

Concepts for Long Pulse Burning Plasma Experiments

Options for increasing the pulse length of the present burning plasma experiment (BPX) have been investigated. These options include higher performance Ohmic heating transformers and steady state cooling of the toroidal field magnet. Higher aspect ratio designs, which may have important advantages for reactor development, have also been studied. Concepts for larger (major radius = 3.5 - 4.0 m) machines using high-field resistive magnets have also been investigated. These concepts could provide a very cost effective means of studying long-pulse, high-gain reactor core operation – a fundamental requirement for fusion reactor operation.

Pilot Plant and Commercial Reactor Design Studies

Concepts are being developed for a minimum size, minimum cost pilot plant that would provide the first demonstration of the production of electricity from fusion power. This work is being carried out in collaboration with Oak Ridge National Laboratory, Ebasco Services, Inc., Ontario-Hydro, and Fusion Power Associates. We are initiating the investigation of reactor concepts that utilize high aspect ratio operation in conjunction with high density, low temperature plasma operation. The Fusion Systems Division continues to participate in the national ARIES commercial reactor design study. We are investigating concepts for commercial reactors that use copper plate magnets at relatively low magnet fields as well as high-temperature-superconductor magnets.

Millimeter-Wave and Infrared Diagnostic Development

A collaboration has been established with the JET tokamak group to implement a gyrotron scattering system (at 140 GHz) for measuring properties of energetic ions by collective Thomson scattering. A collaborative effort is also underway to deploy a 56 GHz gyrotron scattering system on the TFTR tokamak. These collective Thomson scattering measurements will provide important information on the distribution function of an energetic particle component produced in the plasma either by ion-cyclotron heating or fusion reactions.

Plasma Treatment of Waste

An effort has been initiated to investigate the use of plasmas for treating waste at DOE and DOD facilities, hospital waste, municipal waste, and toxic emissions from various industries. A new device concept, the tunable hybrid plasma, has been developed with the objective of increasing the versatility, efficiency, and robustness of destroying volatile organic compounds in the gaseous phase. A joint effort is underway with an industrial partner to utilize special arc plasma technology for treatment of solids. Combinations of various plasma technologies are also being investigated. Concepts for improved sensors for characterizing toxic materials have been developed using scattering, laser-induced plasmas, and laser absorption techniques.

COHERENT ELECTROMAGNETIC WAVE GENERATION DIVISION

The Coherent Electromagnetic Wave Generation Division, headed by Richard Temkin and George Bekefi, conducts research on novel sources of electromagnetic radiation and on the generation and acceleration of particle beams. Research on novel sources of electromagnetic radiation has concentrated on the use of electron beams to generate microwave and millimeter wave radiation. Of particular interest are the gyrotron, the free electron laser (FEL) and the cyclotron autoresonance maser (CARM). These devices are promising for applications which include plasma heating, industrial heating (for example, ceramics sintering) and high frequency radar. Theoretical research investigates the possibility of extending the range of wavelengths to the infrared, optical and x-ray regions. Research is also conducted on the generation and acceleration of electron beams. A novel, induction linear accelerator is operated at high repetition rates and its beam quality is under investigation. Research is underway on the use of high frequency microwaves to accelerate electron beams with very high gradients, up to 200 MeV/m. The demonstration of such high gradients is critical to the planning of future electron accelerators such as the next linear collider. A strong effort in theoretical studies is conducted on the basic equilibrium and stability properties of non-neutral plasmas and intense charge particle beams. These studies contribute to our understanding of electromagnetic radiation generation and particle beam acceleration.

Gyrotron Research

The gyrotron is a novel source of microwave, millimeter wave and submillimeter wave radiation. It uses a helical electron beam in a high magnetic field to generate radiation by stimulated emission at the electron cyclotron frequency. The gyrotron is currently under development for electron cyclotron resonance heating of the ITER (International Thermonuclear Experimental Reactor) and BPX (Burning Plasma Experiment) plasmas. Gyrotrons are also under development for high frequency radar. These applications require tubes operating at frequencies in the range 140-280 GHz at steady-state power levels approaching 1 MW. The gyrotron research group is led by Ken Kreisler.

Research is being conducted on methods of increasing the efficiency of gyrotrons, particularly for application to ITER which requires a 20 MW system. A two-section cavity gyrotron invented at the M.I.T. Plasma Fusion Center has achieved 40% efficiency in 3 μ s pulsed operation at a power level of 1 MW and a frequency near 140 GHz. This cavity may be used in industrial, continuous wave (CW) gyrotrons being developed by Varian Associates in Palo Alto, CA. Several gyrotrons previously designed at MIT have been made into industrial products by Varian. A new gyrotron, optimized for frequencies between 220-280 GHz for use on the BPX experiment, is now under initial test. A gyrotron backward wave oscillator, voltage tunable between 130 and 150 GHz, has been constructed and is under test. A novel gyrotron travelling wave amplifier is being designed. It will have high frequency radar applications of interest to MIT Lincoln Laboratory and the Navy.

The gyrotron research group also conducts research on microwave mode transformers and corrugated transmission line components. These components represent a major advance in the ability to transmit high power millimeter wave radiation over path lengths of 10 to 100 m.

High Power Microwave Research

The cyclotron autoresonance maser (CARM) (Bruce Danly) is a novel, high power microwave source which appears capable of operation at high frequency, into the millimeter wave range. Long pulse ($\sim 1\mu$ s) and short pulse (~ 50 ns) CARM amplifier experiments at 17 GHz have been constructed. The CARM amplifier may be applied as a source for driving high gradient accelerators. A related device, the free electron laser (FEL) (Frederick Hartemann, Bruce Danly) is also promising for millimeter wave generation. A 30 GHz FEL oscillator with a Bragg resonator has produced narrow bandwidth, 1 μ s output pulses from a 300 kV, 40 A beam. Power levels of 0.1 to 1 MW were obtained. Preliminary results have also been obtained in FEL amplifier experiments. A relativistic klystron (Dan Goodman, Dan Birx, Bruce Danly) has operated at X-band (11 GHz) with 100 MW, 20 ns pulses at 40% efficiency. The electron beam for this experiment was produced by an induction linac.

Accelerator Research

An experimental program of research has been initiated on high gradient acceleration by a 17 GHz, RF source (Shien Chi Chen, Bruce Danly). An electron gun is planned in which 5 MW of power at 17 GHz produces a 2 MeV, 50-500 A, 2 ps beam of electrons. The electrons will be generated at a photocathode using a 2 ps, UV laser pulse. In a later phase of this research, accelerator gradients of up to 250 MeV/m are planned. Research also continues on linear induction accelerators in collaboration with Science Research Laboratory. Advances in these accelerators will lead to the generation of high average power microwave sources.

Theoretical Research

Theoretical research has contributed very significantly to our understanding of coherent radiation generation and particle acceleration. Topics covered include coherent radiation sources (CARM, FEL, gyrotron, relativistic klystron, relativistic magnetron), beam-beam interactions, cyclotron resonance accelerators, two-beam accelerators, photocathode design, and other topics. Multimode codes have successfully predicted new phenomena in both the cyclotron autoresonance maser and free electron laser amplifier. A design study has been carried out for MIT Lincoln Laboratory which shows that visible wavelength free electron lasers are capable of very narrow bandwidth operation when dispersive elements such as a grating rhomb are introduced into the cavity. This theoretical effort is led by Jonathan Wurtele, and Chiping Chen and Brian Yang are key contributors.

Industrial Partners

Industrial partners continue to play a major role in research on coherent electromagnetic wave generation and particle accelerators. Science Research Laboratory of Somerville, MA has contributed a high repetition rate, induction linear accelerator. This accelerator is in use in coherent source and accelerator research. Thomson Co. of Velizy, France has contributed components for free electron laser research including an electron gun, wiggler magnet and magnetron driver.

AFFIRMATIVE ACTION

The Plasma Fusion Center is committed to increasing the number of women and minorities at those levels of the work force where there is significant underrepresentation. Our success in meeting this objective is dependent on the pool of applicants available at each level. For example, 82% of both the SRS administrative and support staff are women, while 23% of both support and service staff are black Americans. In these categories, we have found that our search procedures, which utilize both internal and external resources, have turned up an excellent supply of highly qualified candidates. On the other hand, at the SRS technical level, our success is more modest: approximately 5% of SRS technical staff are women, while 12% are minorities, slightly more than half of whom are Asian Americans. These numbers reflect the applicant pool which, for the 6 month period October, 1990 through March, 1991 was 4.8% women and 6% identified as minorities, primarily Asian American. We are attempting to enlarge the reservoir of qualified underrepresented applicants in the near term by more intensive dissemination of job postings to organizations specifically concerned with opportunities for women and minorities and, in the long term, with a substantial K-12 and undergraduate outreach effort which encourages women and minorities to pursue careers as scientists and engineers.

APPOINTMENTS AND PROMOTIONS

During the past year, there have been several important appointments and promotions in Plasma Fusion Center program areas:

Appointments include: Emmanouil Chaniotakis (Massachusetts Institute of Technology), appointed Postdoctoral Sponsored Research Staff in the Fusion Systems Division; Fongyan Gang (University of Texas at Austin), appointed Postdoctoral Sponsored Research Staff in the Physics Research Division; John Goetz (University of Wisconsin at Madison), appointed Postdoctoral Sponsored Research Staff in the Toroidal Confinement Division; Joseph Snipes (ENEA, Frascati, Italy), appointed Experimental Research Scientist in the Toroidal Confinement Division; and Tser-Yuan (Brian) Yang (Massachusetts Institute of Technology), appointed Postdoctoral Sponsored Research Staff in the Coherent Electromagnetic Wave Generation Division.

During the past year, promotions in the Plasma Fusion Center have included: Velmer Brooks, promoted to Fiscal Office Supervisor in the Office of Resource Management; Chiping Chen, promoted to Theoretical Research Scientist in the Coherent Electromagnetic Wave Generation Division; Robin Delaney, promoted to Assistant Fiscal Officer in the Office of Resource Management; Stephen Fairfax, promoted to Deputy Project Manager in the Toroidal Confinement Division; Jun Feng, promoted to Project Engineer in the Fusion Technology and Engineering Division; Joseph Minervini, promoted to Leader of the Superconducting Magnet Development Group in the Fusion Technology and Engineering Division; Zbigniew Piek, promoted to Mechanical Engineer in the Fusion Technology and Engineering Division; Miklos Porkolab, promoted to Associate Director, PFC, and Head of the Physics Research Division; and Dieter Sigmar, promoted to Deputy Director, PFC.

During the past year, the Plasma Fusion Center has also hosted many Visiting Scientists, Engineers and Scholars in the various research programs. They are: Dr. Mohammed Afsar (Tufts University), millimeter wave research; Mr. David Baldwin (Australian National University, Australia), data acquisition; Dr. Joaquim Barroso de Castro (Institute of Space Research, Brazil), theoretical gyrotron design; Dr. Gerhard Berge (University of Bergen, Norway), MHD theory related to Alcator C-MOD; Dr. Daniel Birx (Science Research Laboratory), induction linear accelerator work; Dr. Boris Breizman (Institute of Nuclear Physics, USSR), fusion theory and computation; Mr. Jerome Buzzi (Ecole Normale Supérieure, France), simulation of beam-beam interaction; Dr. Franklin Chang-Diaz (NASA), plasma propulsion; Dr. Xing Chen (Science Research Laboratory), radiation-hardened detectors; Dr. Dennis Clarke (Science Research Laboratory), induction linear accelerator work; Mr. Ronald Davidson Jr. (ASTEX), data acquisition and analysis; Prof. John Davies (Clark University), theory of free electron lasers; Dr. Henry Freund (Science Applications International Corporation), coherent radiation generation by free electron lasers; Dr. Victor Golant (A.F. Ioffe

Physico-Technical, USSR), RF heating; Dr. Daniel Goodman (Science Research Laboratory), induction linear accelerator work; Dr. Frederic Hartemann (Thompson CSF, France), cyclotron autoresonance maser and free electron laser research; Mr. Serge Hould (Centre Specialise de Technologie Physique, Canada), electrical power systems; Dr. Eli Jerby (Tel-Aviv University, Israel), free electron laser theory; Dr. Satish Kandlikar (University of Rochester), superconducting magnet technology; Mr. Shinichi Kodama (Tokai Works, Japan), computer simulation development of plasmas; Dr. Yaroslav Kolesnichenko (Institute for Nuclear Research, USSR), transport theory; Dr. Jurek Koziol (Ferrofluidics), electrode effects associated with seawater MHD; Mr. Phillippe Marmillod (Ecole Polytech Federale, Switzerland), installation of a hybrid computer; Mr. Joel Martin (Centre Specialise de Technologie Physique, Canada), electrical power systems; Mr. Neil Morley (University of California at Los Angeles), high powered, high frequency gyrotrons; Dr. Jacek Myczkowski (Thinking Machines Corp.), theory of lattice gasses to simulate fluid dynamics on special purpose computers; Mr. Scott Nicol (Worcester Polytechnical Institute), stress rupture testing for magnet technology; Mr. Setsuo Nikura (Mitsubishi Atomic Power Industries, Inc., Japan), installation of EDDYCUFF on VAX systems; Dr. Mikhail Petrov (Ioffe Institute, USSR), charge exchange diagnostics; Ms. Sherrie Preische (Princeton Plasma Physics Laboratory), fluctuation diagnostics; Dr. Yi-Kang Pu (SPIRE Corporation), electron cyclotron resonant ion source physics; Dr. Alexey Radovinsky (Moscow Institute for Instrument Building, USSR), magnet system design and construction; Mr. Nicholas Reinhardt (Integrated Applied Physics, Inc.), high power switches and modulators; Dr. Frederick Seguin (American Science and Engineering), γ -ray and X-ray research; Dr. Abhijit Sen (Institute for Plasma Research, India), intense beam physics; Mr. Yasuyuki Tahara (MRI at Mitsubishi Electric, Ako Works, Japan), high field superconducting magnets; Dr. Herman Tsui (University of Texas-Austin), installation of Langmuir probe; Dr. Gerard Vichniac (Kendall Square of Research), lattice gas theory; Dr. Reich Watterson (Science Research Laboratories), novel laser scattering diagnostics; Dr. David Whittum (University of California at Berkeley), advanced accelerators and novel radiation sources; Dr. Xinzhi Yao (The Institute of Physics, PRC), plasma propulsion; Dr. Leonid Zakharov (Kurchatov Institute of Atomic Energy, USSR), MHD theory for tokamak applications; Ms. Ge Zhang (Clark University), theory of free electron lasers; Dr. Zong-Ping Zhao (Tokyo Denki University, Japan), theoretical aspects on the design of high T_c conductor magnets; and Dr. Qinxin Zu (Chinese Academy of Sciences, PRC), plasma diagnostics and RF heating.

GRADUATE DEGREES

During the past year, the following students graduated with theses in plasma fusion and related areas: Jason Bates, M.S. in Nuclear Engineering; Deborah Hanchar, Ph.D. in Nuclear Engineering; David Humphreys, Ph.D. in Physics; Karen Koh, M.S. in Electrical Engineering and Computer Science; Warren Krueger, Ph.D. in Nuclear Engineering; Anita Li, M.S. in Electrical Engineering and Computer Science; James McLaughlin, M.S. in Nuclear Engineering; Fernando Mujica, M.S. in Nuclear Engineering; Kenneth Pendergast, Ph.D. in Nuclear Engineering; Tser-Yuan (Brian) Yang, Ph.D. in Physics; Chan Yoo, M.S. in Nuclear Engineering; and Dimitris Zeritis, M.S. in Mechanical Engineering.

We take this opportunity to wish these graduates success in their future professional endeavors.

RONALD R. PARKER
DIRECTOR
PLASMA FUSION CENTER

Research Laboratory of Electronics

Introduction

The Research Laboratory of Electronics (RLE), the Institute's oldest interdisciplinary research laboratory, was founded in 1946 as the natural evolution of the wartime Radiation Laboratory. Initially, RLE was formed to bring together interests in physics and electrical engineering to work on problems in electromagnetic radiation, circuits, and specialized vacuum tubes. Over the years, however, research interests in RLE have branched out into a number of directions, and in fact, several of these interests have grown to a size which has precipitated the formation of additional laboratories. Research within RLE is conducted by approximately 55 faculty members affiliated with the Departments of Electrical Engineering and Computer Science, Physics, Chemistry, Materials Science and Engineering, Aeronautics and Astronautics, Nuclear Engineering, and Linguistics. During the past year, approximately 250 graduate students and 100 undergraduates worked on research projects within RLE. Major support for this research is derived from the Joint Services Electronics Program (JSEP) of the Army, Navy, and Air Force; other Defense Department agencies; the Department of Energy (DOE); the National Science Foundation (NSF); the National Institutes of Health (NIH); and the National Aeronautics and Space Administration (NASA). In addition, many research projects are funded through industry and private foundations. Although RLE has a very heterogeneous character, its organization can be seen as comprising two major thrusts and seven smaller focus areas. One of the major thrusts is centered on electronics and optics, and the other is centered on language, speech, and hearing. Each of the seven smaller focus areas involves several faculty, often with substantial overlaps in other areas of the laboratory.

ELECTRONICS AND OPTICS

Research in this major thrust area covers the entire gamut of electronics, from the production and characterization of electronic materials to processing techniques, device physics, high-performance integrated circuit design and simulation, and specialized system architectures. RLE's program in this area is highly interdisciplinary, drawing from expertise in physical chemistry, condensed matter physics, electronic materials, device design and characterization, processing innovation, optimal design of high-performance integrated circuits, and the exploration and search of architectural strategies for special purpose applications which include one-dimensional and two-dimensional image processing.

There is a substantial emphasis on the epitaxial growth of materials at atomic layer resolutions using both molecular beam epitaxy and chemical beam epitaxy within RLE. Professor Clifton Fonstad has studied the application of the InGaAlAs semiconductor family in high-performance electronic and optoelectronic devices. In the past year, the thresholds of InGaAlAs laser diodes have been greatly reduced, the quality of heterostructures grown on (111) substrates has been remarkably improved, and the selective etches in AlAs etch-top layers have been improved, and are now being used for a variety of conventional as well as totally new quantum-effect devices. The metal-insulator-doped channel field-effect transistor (MIDFET) has been improved by Professor Jesus del Alamo for high-frequency power applications. With a channel thickness of 100 angstroms, a 19.1 volt breakdown voltage was achieved, providing useful devices for telecommunications. Epitaxial thin films of zinc selenide were deposited on single-crystal GaAs substrates by Professor Leslie Kolodziejski, using a new chemical beam epitaxy facility. During the deposition process, the samples were illuminated by coherent light from a laser source, providing substantial wavelength- and intensity-dependent growth rate enhancement. These results have application in the fields of selective area epitaxy and photo-induced impurity incorporation. Senior Research Scientist Dr. John Melngailis has used focused ion beam techniques to provide direct, maskless, resistless implantation in lithography and in the repair of integrated circuits and masks. Using a new resist, linewidths down to 0.8 microns were written with Ga⁺ ions, resulting in considerably faster writing of original patterns than the more commonly used electron beam lithography. This new technique will be used for making x-ray lithography masks and other applications where direct submicrometer writing is needed. Ion-induced deposition techniques have been studied from a theoretical perspective, and a model of the process based on collision cascades has been developed, which provides substantial predictive power for the design of repair processes where deposition is over complex topography. A new approach to growing low-dislocation-density GaAs on Si was demonstrated by Professor Henry Smith, enabling high-level integration of electronic and optoelectronic circuits. A new understanding of pattern degradation due to diffraction in x-ray nanolithography has been achieved, demonstrating that mask sample gaps could be three times larger than previously predicted. This new result showed that it now appears feasible to manufacture devices at 50-nanometer feature size.

Within RLE, there is an extensive set of both theoretical and experimental investigations of semiconductor surfaces. Results from these studies provide new insight and understanding in surface growth processes as well as the basis for low-pressure reactive-ion etching. Professor Robert Birgeneau has studied the behavior of semiconductor surfaces at high temperatures (over 1,000°K). Although these studies were previously very difficult to conduct, high-

resolution synchrotron x-ray scattering techniques are capable of providing new insights at these temperatures. Studies of flat Ge(111) have indicated that at 1,050°K there is no real phase transition or disordering transition as previously thought. Instead, the topmost layers disorder progressively with increased temperature, while retaining long-range order to at least 1,150°K. Data from these experiments is consistent with a model in which the surface vacancy concentration grows rapidly between 1,000°K and 1,100°K, and then saturates. In studies of vicinal Si(111), results above 1,120°K were consistent with a lattice of steps which wander over large distances. Below 1,100°K, the flat (111) surfaces reconstructed into the well-known 7x7 pattern, causing the flat terraces to grow enormously, and the steps to actually phase separate. Professor Simon Mochrie used high-resolution synchrotron x-ray scattering to study roughened crystal surfaces. For several face-centered cubic metals, he showed that meandering of preexisting steps gives rise to the surface roughness. For the first time, he showed that a clean, close-packed metal surface (Pt(001)) undergoes a transformation from smooth to rough at 1,820°K. Microscopically, this was achieved through the proliferation of atomic steps and islands. Using a new method called "hard-spin mean-field theory", which is quantitatively successful in fluctuation-dominated systems, Professor Nihat Berker developed finite-temperature electronic conduction models, and also derived semiconductor alloy phase diagrams. Professor John Joannopoulos theoretically determined the phase diagram of a miscut Si surface for the first time. It is predicted that a first-order transition line exists between single- and double-step surface phases as a function of temperature and misorientation angle. Such surfaces are important as substrates for epitaxial growth. Professor Sylvia Ceyer, using a unique vacuum apparatus to study surface chemistry reactions, uncovered a new mechanism for surface reaction, involving the fluorine molecule. In this new mechanism, one of the two fluorine atoms was abstracted and bonded to the surface when the molecule impinges on a Si(100) surface, while the other atom was sputtered off the surface. This mechanism is likely to be a source of reactive ion species in a plasma etching environment.

In collaboration with IBM researchers, a group of MIT physicists has made a "single-electron transistor". Whereas conventional transistors turn on and off only once as electrons are added to their gate, the new structure turns on and off each time a single electron is added. This behavior was only observed in extremely small devices (approximately 100x500 nanometers), at which size the gate contains a total of only about 100 electrons. These studies are currently conducted at very low temperatures (approximately 1°K), where the number of electrons on the transistor is forced to be discrete by Coulomb interaction between the electrons. Useful applications will require this unusual behavior to be exhibited at substantially elevated temperatures. Explanations of this periodic structure in conductance as a function of gate voltage are being sought by Professor Patrick Lee. He found that a model incorporating Coulomb blockade effects in the tunneling process accounts for the temperature and magnetic field dependence of the experiment. A novel resonant tunneling structure that uses superconducting counterelectrodes was studied by Professor John Graybeal. Such devices open the possibility to modulate the Josephson current to substantially lower voltage levels than previously possible. This may lead to finite gains in a three-terminal Josephson device.

In the optics research area, Professor Hermann Haus demonstrated the reduction of noise below the shot noise level in a nonlinear optical interferometer. This was achieved through the generation of new quantum squeezed states of light that have reduced fluctuations. These states promise to usher in a new era of precision measurements with optical interferometers. In addition, in collaboration with Professors Erich Ippen and James Fujimoto, the adaptive pulse modelocking principle for short-pulse generation from solid-state lasers was described by a new, comprehensive theory. These structures do not require the interferometric feedback stabilization previously used, and are thus more immune to vibrations. Professor James Fujimoto undertook several studies centered around the use of femtosecond laser generation and measurement technology for the study of ultrafast phenomena. In addition to his work on adaptive pulse modelocking, he developed novel time domain techniques for the measurement of nonlinear index in waveguides. The use of these techniques will be essential for the study of new generation nonlinear optical waveguide materials, such as organic nonlinear polymers or strained-layer quantum well systems which have highly anisotropic optical properties. For medical applications, he developed a new, noninvasive medical diagnostic technique called *Optical Coherence Tomography*. This method is similar to ultrasound B scan tomography, except that it achieves spatial resolutions of a few microns, and hence it is useful in studies performed on the retina and coronary artery *in vitro*. Professor Peter Hagelstein has been building a 191-angstrom wavelength laser. The system is near completion and, due to its relative simplicity and low power requirements, is promising as a candidate for commercial applications. As part of this development, a class of whisper gallery mirror shapes was developed, and a new, practical computation method for treating photon interactions in atomic physics calculations was completed. In addition, a theory describing coherent neutron transfer reactions in deuterated metals was developed, and has accounted for heat and tritium production rates quantitatively, which correlate well with experimental observations. Professor Qing Hu has used a variety of techniques to study high-frequency and high-speed electronic devices. These include terahertz superconducting heterodyne receivers, high- T_c superconducting Josephson devices, photon-assisted transport in quantum point contacts, and terahertz solid-state lasers using quantum well structures.

Professor John Wyatt and his collaborators have been building analog VLSI chips for machine vision. Two very fast camera processor chips that work at over 1,000 frames per second were built. In addition, he has studied the

design and construction of an implantable retina chip for the blind. Early studies indicate that it is possible to stimulate ganglion cells in the retina without stimulating overriding axons. Together with other studies, this result has provided the basic foundation on which the actual retinal implant will be designed. Professor Srinivas Devadas has developed techniques for logic synthesis, formal verification, and testing of VLSI systems. A method to exactly and efficiently compute the delay of a logic circuit that uses the notion of timed test generation was developed. In addition, new definitions of behavioral equivalence that use string function theory were developed. These are important to design verification. A technique for providing capacitance extraction in linear time, developed by Professor Jacob White, was generalized so that the program is useful over a broader class of applications. These techniques are also being exploited by micromotor designers to compute torques. Professor White's waveform relaxation technique for device simulation was accelerated to reduce the number of relaxation iterations by almost an order of magnitude. Numerical techniques to solve the energy balance equation for electron temperature were proven to be numerical robust, and were used to predict substrate currents in MOS devices. Predicted results match measured data on devices with channel lengths as short as 0.16 microns. Techniques for performance-directed synthesis of VLSI systems were studied by Professor Jonathan Allen, including a basic understanding of very high-speed clocking strategies. A novel VLSI database design that provides automatic consistency maintenance between several design representations is nearly complete, and a system to provide architectural design exploration while predicting the consequences of speed performance of the resultant design is also under study.

LANGUAGE, SPEECH, AND HEARING

RLE has a large coordinated effort in speech, hearing, and the phonological aspect of language. This effort unites contributions ranging from auditory physiology to auditory psychophysics, speech communication, and linguistics. The scope of this effort has increased further through new projects that study a wide variety of forms in sensory communication.

In the speech communication area, new models to access words from acoustic data are being developed in terms of hierarchies of features made apparent through sequential detection of a set of properties in a sound wave. These studies have led to the construction of a lexicon based on feature hierarchies. Additional research projects include continuing studies of processes of normal and impaired speech generation, including models of the speech planning process, the control and coordination of articulatory movements in speech production, mechanisms of sound generation in the vocal tract, and the simulation of these processes by a speech synthesizer. Using an electromagnetic midsagittal articulometry apparatus, Senior Research Scientist Dr. Joseph Perkell has studied tongue body and lip movements with relation to acoustic targets. His initial results indicated that these targets are not invariant, but vary in a contextual manner. Studies of vocal hyperfunction were conducted using noninvasive, indirect measurements of glottal air flow, transglottal air pressure, and the acoustic signal. This common functional voice order is usually due to excessive, habitual loudness, as well as other contributing factors. The speech of cochlear implant patients has been studied by Dr. Perkell, and has revealed that these patients discriminate relatively gross properties of the speech waveform, such as fundamental frequency and sound pressure level, and make "postural" adjustments to the corresponding speech parameters upon activation of the speech processor of the cochlear implant. With experience, these patients make further speech changes, such as adjustment in formant values, as well as adjustments in articulation to convey phonemic contrasts.

In the sensory communication area, Professor Louis Braid; Professor Richard Held; Senior Research Scientist Nathaniel Durlach; Principal Research Scientists Dr. William Rabinowitz, Dr. Charlotte Reed, and Dr. Patrick Zurek; and Research Scientists Dr. Xiao Dong Pang and Dr. Mandayam Srinivasan studied multimodal sensory perception in a variety of applications. Noise rejection features are being incorporated into hearing aids through the use of microphone arrays and adaptive processing in order to attenuate noise signals arriving from directions distinct from that of the target. Work on human-machine interfaces for teleoperators and virtual environments was focused on manual sensing and manipulation as well as sensory-motor adaptation. Dr. Srinivasan has modeled the mechanoreceptors embedded in the skin as contributors to the human sense of touch. A series of mechanistic models of the human finger tip, using finite element analysis, was used to develop a computational theory of touch that integrates the mechanics, identification, and control aspects of grasping compliant objects with compliant finger pads.

Within RLE, there is a wide variety of auditory physiology studies conducted in conjunction with the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary. Professor Nelson Y.-S. Kiang continued studies of the relationship of single neuron activity in the brain to electrical potentials recordable from the scalp. Various kinds of lesions affect specific components of auditory-evoked responses differently, and give clues to the cellular generators. These results may be clinically useful in diagnosing neurological disorders. Professor William Peake and Research Scientist Dr. John Rosowski developed a model that allows predictions of expected hearing levels in cases where the middle ear ossicles are not functioning properly, and hence the sound acts directly on the inner ear. These studies have indicated that a good hearing level can be achieved with a simple surgical procedure, which can be tailored to ensure the best hearing results. Several studies of the electrical stimulation of the human auditory system

were led by Principal Research Scientist Dr. Donald Eddington. A single fiber model was used to investigate interaction between sequential stimuli, predicting the temporal behavior of neuron sensitization by means of charging the nerve membrane. This model has been used to predict models from psychophysical experiments in implanted human subjects with good results. In addition, in studies designed to test the ability of subjects to recognize speech without lip reading, results indicated that speech reception may show a significant correlation with the state of the auditory nerve. New sound processing schemes that minimize the interaction of electric fields between implanted electrodes have enabled several subjects who use cochlear implants to increase speech reception scores by as much as 20%. The physiological effects of medial olivocochlear efferents (MOC), which terminate on outer hair cells in the mammalian cochlea, were studied by Principal Research Scientist Dr. John Guinan. Data showed that efferent stimulation inhibited stimulus frequency otoacoustic emissions, and controlled the gain of an amplifier which is responsible for the sensitivity of the cochlea. This work demonstrated an efferent effect on an otoacoustic emission, which may be generated primarily by linear processes, and may directly reflect efferent effects on the cochlear amplifier. Research Scientist Dr. Bertrand Delgutte has developed a state-of-the-art computer facility for auditory research, incorporating the generation of acoustic stimuli and the processing of electrophysiological, acoustic, and mechanical responses recorded from the air and the brain. The facility is now being used to study how neurons in the auditory nerve and the cochlear nucleus respond to sounds that produce the sensation of musical pitch. Results have suggested that pitch corresponds well with the most frequent interval between nerve impulses in the entire array of auditory nerve fibers.

FOCUS AREAS

Atomic, Molecular, and Optical Physics

Stimulated Brillouin scattering in optical fibers was studied by Professor Shaoul Ezekiel through the construction of stimulated Brillouin lasers in fiber ring cavities, resulting in very narrow linewidths. These lasers can be used for a variety of applications that require laser linewidth narrowing without feedback, wide-band frequency shifting and frequency modulation, generation of tunable, narrow linewidth microwave sources, and a variety of optical sensors including the first all-solid-state ring laser gyroscope that uses such lasers. Professor Daniel Kleppner studied the connections between nonlinear classical mechanics and quantum mechanics through an experimental investigation of "quantum chaos". Both theoretical and experimental techniques for computing the spectra of a highly excited atom in a strong magnetic field have led to excellent agreement, providing an important advance in the understanding of nonseparable quantum systems. In another theoretical development, the complete spectrum, which is generally believed to be random, was shown to originate from a fundamentally orderly and underlying structure. Professor David Pritchard demonstrated the first atom interferometer that involves the use of three gratings for the diffraction of sodium atoms. These gratings have a period of 0.4 microns, and the resulting interferometers are valuable for three general classes of measurements. They can be used for the measurement of inertial effects, and have approximately 10^{10} times the sensitivity to the rotation of a laser gyroscope with the same beam geometry. These improvements in atom optics may ultimately permit the construction of gyroscopes that are good enough to perform tests of relativity.

Plasma Physics

For many years, a continuing trend in RLE has been the study of plasmas and the generation of high-power radiation. Professor George Bekefi provided coherent radiation generation by relativistic electron beams utilizing a novel microwiggler for free-electron laser applications. Coherent radiation at a wavelength of 400 nanometers can be generated by such an apparatus. He also built a 33.3 gigahertz free-electron laser where the cyclotron rotation of the electrons in the uniform axial field opposes the rotation in the helical wiggler field in a novel way. Professor Abraham Bers has shown that the space-time evolution of an unstable wave by lowest order nonlinear coupling to two damped waves leads to spatiotemporal chaos. This state is characterized by the chaotic dynamics of quasi-soliton structures, and is distinct from ordinary turbulence. The plasma processes involved in a phenomenon known in astrophysics and generically called *magnetic reconnection* has been studied theoretically by Professor Bruno Coppi. Simultaneously, experiments in fusion research on high-energy plasmas have revealed significant instabilities that provoke a "crash" in temperature in the central part of the confined plasma column that produces magnetic reconnection. These instabilities can be a serious obstacle and prevent a magnetically confined plasma from reaching the conditions necessary to ignite by fusion reactions. The theoretical understanding of both of these phenomena has recently been tested experimentally, providing a common theoretical basis for two seemingly disparate phenomena. The medium-sized research tokamak Versator has been used by Professor Miklos Porkolab to study a variety of plasma phenomena with a primary emphasis on basic investigations of radio-frequency plasma interactions, including heating and noninductive current drive, in addition to studies of plasma stability and the development of novel diagnostics. Many of these studies have led to important contributions to the design of the Alcator C-MOD tokamak research facility as well as other university and industrial collaborations outside of MIT.

Radio Astronomy

The research of Professors Bernard Burke, David Staelin, and Jacqueline Hewitt has addressed five different areas. These include surveys of radio sources, the search for gravitational lenses, cosmological implications of gravitational lenses, the extension of very-long-baseline-interferometry (VLBI) methods to space, and the search for exoplanetary systems. The number of known radio sources in the southern hemisphere has increased by a factor of ten due to a large, recent survey. The study of gravitational lenses has led to new techniques for the evaluation of the Hubble constant, which is consistent with the value determined by conventional methods of optical astronomy. It is interesting to note that the VLBI technique to improve the angular resolution of radio telescopes by four to five orders of magnitude is now mature, with angular resolution being limited by the size of the Earth. Now, a new effort seeks to build satellite-borne radio telescopes that will increase the baseline significantly further. Missions for the launching of these satellite telescopes are expected to be flown in the 1994-95 time frame. Even further afield are plans for the possible discovery of planets orbiting other stars and for studying the physical characteristics of such systems. It should be possible to detect such exoplanets by direct means utilizing a system placed on the moon. Possibilities for such a system have already been published, and a scientific working group has been formed to layout an orderly program for developing missions in both the near-term and the future. Professor David Staelin continued the development of passive microwave techniques for sounding the terrestrial atmosphere from satellites. In addition, following another interest, he developed new mathematical techniques to significantly improve methods conventionally used for experimentally modeling and optimizing manufacturing processes. These methods require fewer industrial experiments to reach a given level of process performance, and apply appropriately to a wide range of practical situations. Principal Research Scientist Dr. Philip Rosenkranz focused his studies on the emission and propagation of microwave thermal radiation in the Earth's atmosphere and from its surface. A variety of phenomena were revealed, leading to more accurate algorithms for remotely measuring atmospheric parameters from satellites.

Digital Signal Processing

The Digital Signal Processing Group, led by Professor Alan Oppenheim, focused on four major areas. One involved the development and application of new techniques for single and multisensor signal enhancement and noise cancellation. A second area involved exploiting the properties of $1/f$ processes for spread spectrum communications and waveform design. A third major emphasis is the use of chaotic behavior in nonlinear dynamical systems in a variety of signal analysis and synthesis contexts. Research continued on the combination of numerical and symbolic techniques in signal processing. Of particular interest during the last year was the development of a novel method for analysis and synthesis of self-similar signals, such as those provided by fractal modulation. These studies will lead the characterization of a new set of basis vectors for such signals which are widely prevalent in applications.

Advanced Television and Signal Processing

Professor Jae Lim is leading a major activity focused on the complete design and specification of an all-digital high-definition television (HDTV) system. This system will be entered in the upcoming Federal Communication Commission competition for an American HDTV standard, and a real-time all-digital system for purposes of evaluation is being built through collaboration with an industrial partner. Many techniques for coding which provide image compression and error correction, together with high-quality audio, are being specified and evaluated through simulation techniques. Professor William Schreiber is completing the design of a hybrid analog-digital system designed to provide spectral efficiency and graceful degradation in areas of marginal reception.

Electromagnetics

Professor Jin Au Kong and his research group have worked on electromagnetic wave theory problems and applications. They have studied applications to remote sensing of the Earth and its environment, geophysical subsurface probing, evaluation and simulation of airport landing systems, and microwave and millimeter-wave integrated circuit studies. Realistic theoretical models that are applicable to active and passive remote sensing, atmospheric precipitation, vegetation, and snowfields were developed. The development of theoretical models has been strongly motivated by the need for accurate data analysis and interpretation, as well as scene simulation characteristics. The concept of polarimetric passive remote sensing was experimentally verified, and holds great promise in microwave observation and monitoring of the Earth's terrain and environment.

Optical Communications

Professor Jeffrey Shapiro and Research Scientist Dr. Ngai Chuen Wong developed a theoretical proposal for zero-error-probability phase communication at finite average photon number. This work may lead to an architecture for precision measurement in which absolute precision (to a prescribed number of decimal places) is assured, as opposed to the usual root-mean-square error specification. In addition, an optical parametric oscillator for ultrahigh-

precision optical frequency division is being built. This new divider can be used as an active gravity wave interferometric detector for use in experiments at MIT and elsewhere. A wideband optical frequency comb generator based on this optical parametric oscillator may address the problem of channel identification in a terahertz-bandwidth communication network, the study of which is underway by a consortium of investigators in RLE, the Laboratory for Information and Decision Sciences, and Lincoln Laboratory. Senior Research Scientist Dr. Robert Rediker studied the operation of a fiber-coupled external cavity laser. All inputs to this laser's cavity are adjusted to have the same phase through provision of feedback from the individual semiconductor diode facets. This has led to higher power coherent lasers based on semiconductors, leading to active phase locking. These techniques may also be used to remove aberrations in an optical wavefront caused by atmospheric turbulence.

In addition to the focus areas described above, several other research directions have been pursued within RLE. Professor Campbell Searle constructed computer models for the mechano-electric transduction process in hair cells, leading to significantly different models than those previously provided in the literature. Professor Donald Troxel has developed the Computer-Aided Fabrication Environment software facility for use in integrated circuit manufacturing. Through the development of a process flow representation, both the actual fabrication of integrated circuits as well as the simulation of this processing can be driven from the same computer-manipulable representation, thus shortening the development time for new and improved semiconductor fabrication processes.

JONATHAN ALLEN

Sea Grant College Program

The Sea Grant College Program, which is modeled after the Land Grant Program, includes funds for research, education, and technology transfer directed toward wise utilization of marine resources. MIT received one of the first grants in 1969 and has been a leading participant in the national program ever since. By 1976 MIT's Sea Grant contribution was so significant that the Institute was designated a Sea Grant College Program, the only private university to receive this recognition. (The University of Southern California and Woods Hole Oceanographic Institution are the other private institutions participating in Sea Grant). Sea Grant College status also confers a responsibility to work with marine researchers throughout the Commonwealth.

There are 29 Sea Grant Programs located in the coastal and Great Lakes states. Funds are distributed among programs in a competing grant process from the National Oceanic and Atmospheric Administration through its National Office of Sea Grant. Each program is required to match its federal grant by one-half with contributions from non-federal sources, including industry, state and local governments, universities, and private foundations. Congress established this matching provision to ensure that Sea Grant universities would be responsive to public and industry needs, and to encourage cooperation between those who do the research and those who use it. Sea Grant provides funds explicitly for technology transfer through its mandate for advisory services and education as well as research.

Last year the national Office of Sea Grant awarded MIT \$1.67 million; essentially the same as the previous year. MIT, industry partners, the Commonwealth, the Massachusetts Water Resources Authority (MWRA), and the US Olympic Committee provided nearly \$1.4 million in matching funds. In addition, MIT Sea Grant also received more than \$1.1 million in related research from other federal agencies. In all, these funds supported about 20 faculty members and 30 students from seven departments including Civil, Chemical, Ocean and Mechanical Engineering; Electrical Engineering and Computer Science; Aeronautics and Astronautics; and Earth, Atmospheric and Planetary Sciences (and partial support for faculty at UMASS/Boston, Boston University and Northeastern University).

RESEARCH

The direction of Sea Grant research at MIT is guided by both the unique resources of the Institute and the needs of the marine community. This research is currently focused in six theme areas: automation in the manufacture of marine systems, marine biotechnology, ocean and coastal processes, ocean engineering, technology development and management for ocean uses, and unmanned underwater systems. Investigators from other Massachusetts universities participate in some of these research areas. Each of these areas is discussed below.

Computer-aided engineering continued as one of Sea Grant's strongest areas of activity. *Automation in the Manufacture of Marine Systems* has focused on geometry and methods of shape representation. Sea Grant funding was applied to new methods for representing shape in efficient manners; for example, medial-axis transforms are being investigated. Funding from other sources focuses on transferring geometric data between design and manufacturing systems, a particularly important step in developing and implementing quiet, efficient propeller systems. The David Taylor Research Center in Bethesda, Md., provides funding to extend the theoretical understanding and numerical techniques for describing the performance of propellers. The automation theme area has attracted substantial collateral support from the Naval Sea Systems Command and the Office of Naval Research (ONR).

The overall objective of Sea Grant's research in *Marine Biotechnology* is the advancement of technology that can contribute effectively to better use of the biological resources of ocean and coastal biosystems. Recent and ongoing research has focused on the development of controlled-release technology, the investigation of the beneficial effects of marine products in controlling human degenerative diseases, and the improvement of technology for food processing.

Interdisciplinary Sea Grant investigations of *Ocean and Coastal Processes* seek to describe and model the behaviors of currents, sediments, and chemical compounds. Projects during the past year included studying the exchange of toxic organic compounds between sediments and the water column, and determining the particle scavenging rates and residence times in Massachusetts Bay. Other researchers worked to develop a

way to remove trace contaminants from coastal, surface, and groundwater sources. Research support in this theme area has also come from the MWRA. Additional research on Massachusetts Bay and Boston Harbor is carried out under Sea Grant's first Marine Center project (see below).

Through Sea Grant's advisory activities, undergraduate students have been working on a variety of coastal problems, such as the noxious algae that have recently spread from Swampscott to Lynn and to Revere; the PCB cleanup in New Bedford Harbor; and where to place dredge spoils from proposed dredging of Boston Harbor ship channels. Professor Philip M. Gschwend of Civil Engineering oversees this area in Professor Keith Stolzenbach's absence.

Sea Grant research under its *Ocean Engineering* theme has focused on the dynamics of large-scale ocean vortices. The development and evolution of large-scale vortices has important impacts on offshore engineering and geophysics. Vortices appear to be a dominant influence in diverse areas ranging from oscillation of flexible structures to ocean current dynamics and beach erosion. This research combines analytical, numerical, and experimental methods. The goal of Sea Grant's research is to develop relatively simple rational models of these extremely complex phenomena by isolating their root causes and by explaining large-scale vortices in terms of the stability properties of the time-average flow. The validity of the approach has been successfully tested in several applications, including the interaction of ship wakes with the ocean surface. Additional financial support has been received from ONR. In related research, Sea Grant is investigating new structures for lightweight hulls for very deep submersibles (6000m).

In Sea Grant's *Technology Development and Management* theme area, the program investigates new programs that may develop into future theme areas or that may show particular promise in solving important marine related problems. Theme areas in Automation and in Unmanned Underwater Systems began as projects in *Technology Development*.

In order to more fully exploit opportunities for cooperative, multi-sponsor programs with industry, Sea Grant established the Marine Center project under its *Technology Development* theme area. Sea Grant funds are used for initiating research projects, and matching industry and government funds are obtained to expand research opportunities. Initially, Sea Grant focused on using joint research activities as a powerful technology transfer mechanism. The projects undertaken were extensions of research projects that had been carried out under Sea Grant funding for several years. These projects represented a bridge between Sea Grant's Collegium program and its basic research program, closely tying together its research and advisory programs.

Because Sea Grant needs more "leverage" from its funds, the program decided to undertake a few major multi-year, multi-sponsor research projects under the Marine Center concept. Such a concept was tested in developing the automation theme area in which Sea Grant funds were used to establish a small group of researchers with expertise and interest. With modest Sea Grant matching funds the researchers obtained long-term funding from industry and other government agencies.

Sea Grant established a multi-sponsor Marine Center research project focusing on pollution in Boston Harbor and Massachusetts Bay as its first Marine Center project. Sea Grant already has strong state support from the MWRA and there are indications of other significant support. This project compliments Sea Grant's coastal processes research and involves researchers at UMASS/Boston as well as those from MIT.

The second major project carried out under the Marine Center involves underwater systems. Titled "Autonomous Underwater Vehicles," the project encompasses a broad program aimed at making autonomous underwater systems useful tools for coastal and oceanic research and/or monitoring programs. The projects focus on intelligent control systems and applications of artificial intelligence. The concept of layered control (subsumption architecture) receives special emphasis. The project is sponsored by Sea Grant, Charles Stark Draper Laboratories, Northrop Corp., and International Submarine Engineering Ltd., with funding expected from several government agencies.

Other work on underwater systems is carried out under Sea Grant's research theme area *Unmanned Underwater Systems*. In this area, Sea Grant is investigating how autonomous unmanned vehicles might contribute to the study of large vortical patterns in the ocean. Researchers are also looking at fin-like propulsors to achieve higher energy efficiency. Developments in underwater vehicle research can be tested, in part, at Sea Grant's Underwater Work Systems Laboratory at the Boston National Historical Park in Charlestown. To help the National Park Service in its marine education efforts, MIT Sea Grant installed an educational display to teach visitors about underwater vehicles. The display is an illustrated survey of underwater research vehicles, including at time line that reviews highlights of underwater vehicle development from ancient times to today and a depth chart with maximum operating depths for various submersibles. The park attracts about 1 million visitors annually. Professor Henrik Schmidt of the Department of Ocean Engineering oversees this research area as associate director for research and James G. Bellingham directs the AUV Lab.

An interactive computer-based information/education program about underwater vehicles developed and maintained to augment the Charlestown display was field tested at the New England Aquarium with such success (and reliability) that the Aquarium is now seeking funds to obtain an identical configuration for a permanent educational display.

EDUCATION

The educational goals of Sea Grant are to provide learning opportunities to university students, professionals, and the public. Support for graduate students is included in almost every research project. In addition, the program continues to provide major support for marine-related Undergraduate Research Opportunities Program (UROP) projects.

Sea Grant directly provides \$25,000 shared costs and support from from other departments (primarily Ocean Engineering), and contributions from Draper Laboratories raise the total funding by \$10,000 to \$20,000. About a dozen UROPs are supported during the spring and fall terms and about eight students are supported for a full summer. Undergraduates from Aeronautics and Astronautics, Civil, Ocean, Mechanical, and Electrical Engineering and Computer Science were represented, as well as students from Physics and Earth, Atmospheric, and Planetary sciences.

The Dean A. Horn Award was established in 1982 to honor the contributions of a former Sea Grant director. The award is given to the marine-related UROP project that best reflect Mr. Horn's high regard for significant innovative marine research projects carried out with competence and reported with clarity.

In September 1990, the award was given to Don Lee, a senior in Course VI for his research on autonomous underwater vehicles. An honorable mention was given to Javier Segovia for work during his freshmen year on documenting, describing, and improving a computer program modeling the rowing process in typical shells.

The 1990 Sea Grant Lecture was presented by Dr. John A. Knauss, Under Secretary of Commerce for Oceans and Atmosphere. "The Health of the Ocean or Boston Harbor is not the Sargasso Sea" was presented on October 25, 1990. Dr. Knauss (MIT '40) cautioned about generalizations about the health of the oceans based on data from the perimeters i.e. harbors, estuaries, and bays. He pointed out that new techniques—and long-term data—are needed to help us distinguish between natural long-term variability and changes caused by man.

MIT Sea Grant had its third nominee accepted as a John A. Knauss Sea Grant Policy Fellow, which permits graduate students to participate actively in Congress or NOAA.

PROGRAM MANAGEMENT

The program director is Chryssostomos Chryssostomidis, professor in the Department of Ocean Engineering. Associate directors for research are Henrik Schmidt, associate professor in the Department of Ocean Engineering and Professor Philip M. Gschwend, who was acting director of the Parsons Laboratory last year. Norman Doelling, assistant director, oversees the operation of Sea Grant Advisory Services and Education. New to the staff was Tekla McNerny, who provides secretarial support for our communications/information group and assists design of publications. Dr. Thomas Consi, a post-doctoral associate last year, became a full-time research engineer this year.

MIT Sea Grant administers the Doherty Professorship, endowed by the Henry L. and Grace Doherty Foundation in 1973, for junior faculty at the Institute. Continuing to hold the appointment is Henrik Schmidt, associate professor of Ocean Engineering, who is conducting research in acoustics. In the spring 1991, Professor Harri Kytomaa of the Department of Mechanical Engineering was awarded the two-year chair for his proposal "Dynamic Resuspension and Settling of Particulate Beds" and Professor Linda Cima of the Department of Chemical Engineering for her proposal "Marine Biopolymers for Medical Uses: Cell Interaction with Alginate."

TECHNOLOGY TRANSFER

Sea Grant's legislation explicitly provides funds for technology transfer as an integral part of the program. Additionally, the technology transfer projects are designed to bring current user needs to the attention of MIT Sea Grant researchers. Thus, technology exchange may be a better description of our efforts.

The *MIT Sea Grant Marine Industry Collegium* promotes the active transfer of marine research and technology through the sponsorship of workshops, distribution of publications and research reports, and direct interaction with members. Since 1975, the Collegium has provided member organizations with the opportunity to attend several technical workshops and symposiums per year. Recently, the Collegium program has collaborated with other campus organizations in the sponsorship of symposiums. During the past year, Collegium workshops have included sensor and navigation issues for unmanned underwater vehicles, biosensors for the marine environments; and interaction of flow fields with cables, flexible risers, and tethers.

MIT Sea Grant's *Center for Fisheries Engineering* is recognized as an important national resource for technical studies of fishing gear and vessel design. Using tow tanks at MIT and at the David Taylor Research Center, in Bethesda, Md., the Sea Grant center tests scale-model trawl systems and conducts courses for fishermen. Courses have been offered that demonstrate trawl gear from both coasts, including trawl door behavior and the effects of the seabed on net behavior.

The *Massachusetts Marine Liaison Service (MMLS)* works with town managers, harbor masters, and state agencies, identifying local needs and addressing them. For example, MMLS released a draft of a primer on water quality issues in Massachusetts' coastal zone for use by town officials. In addition to presenting causes and effects of water pollution problems, the sourcebook offers information about legislation and agencies governing the Commonwealth's water resources. Fulfilling the liaison function, MMLS personnel chairs the advisory board to the Massachusetts Coastal Zone Management Program and serves on a special working group for the Massachusetts Bays Program. MMLS continues public educational outreach efforts through exhibits, participation in conferences and festivals, and publication of articles in *Commercial Fisheries News*.

In disseminating Sea Grant information, the MIT Sea Grant *Communications/Information Service* produced a variety of publications in 1990-1991, including technical reports, brochures, directories, and a quarterly newsletter. The service also continued its involvement in a regional magazine (circ. 12,000) that informs readers about Sea Grant's research in all of New England. Some of the more notable publications produced by the service included a chronology on the history and events surrounding the degradation and cleanup of Boston Harbor, a directory of marine-related research at MIT, and a guide to aquaculture organizations in the Northeast. In addition, the service worked with the New England Aquarium to install a computer interactive display that will reach an estimated 1 million visitors annually. Working with the press resulted in stories in *The Boston Globe* and other New England newspapers, as well as national and international trade journals.

During the year, MIT Sea Grant experimented with a new component for its advisory service. It started an effort to support faculty and graduate students in public service application of new technology to marine and coastal problems in Massachusetts. Sea Grant's initial efforts were judged extremely successful by its site review team and the program has been encouraged to continue support for this activity. This project provides additional support for Sea Grant's research projects and for its graduate students.

Technology and Development Program

INTRODUCTION

The Technology and Development Program's (TDP) primary objective is to provide a focus at MIT for research and education related to the role of science and technology in the socioeconomic growth of developing countries. The multi-disciplinary program is a mechanism to bring faculty and students at MIT together with faculty and staff in foreign universities, research institutions, and government organizations. Its specific objectives are to:

- Promote an awareness of the relationship between science, technology, and development on the part of faculty and students at MIT;
- Provide a focal point for the activities of faculty, students, and visiting scholars interested in the field of technology and development;
- Assist the faculty, students, and staff of collaborating institutions in other countries to develop research and academic interests consistent with their national needs;
- Serve as a contact for interested organizations outside MIT (government, academic, private sector) to access the Institute's resources and its knowledge of developing countries -- particularly of their socio-economic and technological problems.

The TDP carries out its objectives through research, academic programs, and contacts with international and national organizations that are concerned with or have an interest in, broad areas of technology and development. These programs are conducted solely on the basis of strong MIT faculty support and willingness to participate. In order to fully utilize the resources available at MIT, the TDP's organizational structure is designed to interact with other academic departments and research centers, which the TDP calls upon for support whenever appropriate.

CURRENT RESEARCH PROGRAMS

In October 1990, TDP finalized a Collaborative Program on Science, Technology, and Development between MIT and the American University of Beirut. The purpose of the program is to focus on specific joint research projects which are relevant to the reconstruction and redevelopment of both physical and institutional resources in Lebanon. The initial phase of the program is for two years. Four research projects were initiated at the beginning of the 1991 Spring Semester. These projects are being conducted in four separate MIT organizational units including: the Civil Engineering Department; the Laboratory for Electromagnetic and Electronic Systems in the Electrical Engineering Department; the Urban Studies and Planning Department; and the recently established Center for Educational Computing Initiatives. To date, MIT participation in these projects has included 4 faculty, 4 research staff and 5 graduate students. Visitors from AUB have included 5 faculty members.

CURRENT EDUCATION INITIATIVES

The TDP-sponsored Middle East Program at MIT completed its fifth year with 10-12 graduate students participating each semester. The program enables students with an interest in the Middle East to develop an expertise in the area in addition to their own academic fields of specialization. The program examines the processes of socio-economic change, technological development, political change, institutional development, capital flows, and business and investment patterns in the region. Three interdepartmental courses are offered by the program: Politics, Growth, and Development in the Middle East; Technology, Business and Public Policy in the Middle East; and Reconstruction. The "Reconstruction" subject, which this year focused on Lebanon, covered such areas as: the influence of culture on reconstruction, strategies for the preservation and/or reconstruction of urban environments and spaces, and on the determination and analysis of supply-side issues (ranging from specific inputs such as manpower and construction materials on the one hand, to financing and administration on the other hand). The Middle East Program is under the direction of Professor Nazli Choucri, TDP Associate Director, and involves faculty from the Department of Political Science, Department of Economics, the History Faculty, the Department of Urban Studies and Planning, the Sloan School of Management, the Department of Civil Engineering, the Science, Technology and Society Program, and the Aga Khan Program in Islamic Architecture.

ORGANIZATION

The TDP Director is Professor Fred Moavenzadeh, George Macomber Professor of Construction Management in the Department of Civil Engineering. Professor Nazli Choucri of the Department of Political Science is the Program's Associate Director and Chairman of the Policy Committee. Other Committee Members are Professors Moavenzadeh, Daniel M. Holland of the Sloan School of Management, and Jack R. Ruina of the Department of Electrical Engineering.

FRED MOAVENZADEH

Technology Licensing Office

The primary goal of the Technology Licensing Office (TLO) is to facilitate the transfer of technology from MIT (and the Whitehead Institute) to industry, and thereby, to benefit the public good through the development and sale of subsequent commercial products. A secondary goal is to generate unrestricted income to motivate inventors and to support research and education at MIT. The TLO staff of 16, with 10 professionals and six support personnel, are responsible for identifying marketable technologies, managing their patenting and copyrighting process, finding licensees, and negotiating licenses.

In Fiscal Year (FY) 1991, the TLO received approximately 280 new disclosures. Patent applications were filed on approximately 40 percent of the disclosures (120 applications). Cost reduction in response to increasing legal costs has led to greater selectivity in filing patent applications such that the percentage of cases for which applications were filed has declined from 64 percent five years ago.

In Calendar Year 1990, 112 United States patents were issued to MIT. Consequently, for the fifth consecutive year, MIT has been granted more patents than any other United States university.

Cash receipts from licenses and from cash out of equity were \$5.4 million, up from \$4.1 million in FY 1990 and \$3.1 million in FY 1989. In addition to cash, the TLO sometimes received equity in lieu of up-front licensing fees from newly formed companies. These equity shares were kept in the "TLO Fund" by the Treasurer's Office. There were no new major startups this year, but two earlier startups (Immologic Pharmaceutical Corporation and Interneuron Pharmaceuticals, Inc.) went public. We also realized almost \$1 million in cash from equity received in previous years.

This year we initiated a program with Information Systems to redesign our computerized database and accounting systems. Version 1.0 of the new system (based on Ingress) was installed in June, with "shakedown" planned for the summer. The rapidly increasing number of active licenses and active inventions has made a faster, more flexible system a necessity. Automated invoicing has already led to an increase in the efficiency of collection of patent reimbursement costs and royalties and in the disbursement of inventors' royalties. We hired a new financial assistant (Denise Vaillancourt) and promoted Irene Abrams, former financial assistant, to Licensing Associate to help in the maintenance of current licenses.

Our two year plan to improve software support was completed with the hire of David Charron as a licensing officer. Mr. Charron is a mechanical engineer with experience in industry and in software licensing at Stanford University's Office of Technology Licensing. Mr. Charron is part of a four-person team in the TLO which also provides support for Lincoln Laboratory. Licensing of Lincoln Laboratory inventions continues to grow. Our Lincoln Laboratory licensing program, including the Technology Transfer Agreements and Collaborative Research Agreements initiated last year, is used as a model for other national laboratories.

JOHN T. PRESTON

Whitaker College of Health Sciences and Technology

The Whitaker College of Health Sciences and Technology (Whitaker College) is a major interdisciplinary academic and research entity at MIT. Many areas of research and teaching that are pertinent to health, both fundamental and applied, have been developed and incorporated into Whitaker College.

The activity in the Whitaker College currently includes the Department of Brain and Cognitive Sciences, the Clinical Research Center, the Division of Toxicology, the Center for Environmental Health Sciences, and several interdisciplinary educational and research programs which are administered directly by the College headquarters.

We report here on the events and new initiatives of programs that operate within the College core. The activities of the above departments and centers are reported separately.

Programs in bioengineering focus on (1) biomedical imaging including radiological sciences, and (2) medicinal chemistry and drug delivery systems.

BIOMEDICAL IMAGING AND COMPUTATION

The Whitaker College Biomedical Imaging and Computation Laboratory was established in 1988 to serve as a nucleus and base for medical and biomedical imaging research activities within the MIT community. In addition to providing a site for the primary faculty associated with this effort, the goal of the laboratory is to encourage the collaboration of faculty, research staff, and students in relevant departments on basic research on imaging technologies and image processing and display methods.

The computational resources of the laboratory are currently based upon seven SUN Microsystems workstations, a Silicon Graphics workstation, and several MacIntosh and IBM personal computers connected on a local network with a gateway to the MIT Campus Network. An Eikonic optical scanner is available for direct entry of microscope slides and photographic images.

Operational since January of 1989, the laboratory is under the direction of Professor Derek Rowell of the Department of Mechanical Engineering and the Whitaker College. Other primary faculty include Professor Gordon Brownell (NED/WC), and Jacquelyn Yanch (NED/WC). Facility users are associated with the National Magnet Laboratory, the Departments of Mechanical and Nuclear Engineering, the Harvard-MIT Division of Health Sciences and Technology, and the Department of Brain and Cognitive Sciences. In addition, the laboratory has collaborations with colleagues at the Massachusetts General Hospital and several other Boston area hospitals.

Research activities include a broad range of applied and developmental topics. A considerable effort has been placed upon the development of general purpose advanced image processing and the rendering of software to provide a general resource for image processing. Applications have included topics in cardiology, biomechanics, blood flow MRI imaging, three dimensional reconstruction, Monte-Carlo simulation methods for nuclear medicine, and positron emission tomography (PET) imaging.

The computational research interests of Professor Yanch have created a new direction of inquiry which operates in parallel to efforts in medical imaging. The goal is the understanding and improvement of radiation therapy. Much of the research involves intensive computation effort which is well met by the workstations available in the lab. Computational activities deal with the Monte-Carlo calculation of radiation penetration and dosimetry for neutron capture therapy, the simulation of performance of imaging systems, and the improvement in image quality by techniques such as simulated annealing. These computational tools have also been used for teaching in the Department of Nuclear Engineering and in HST and during IAP.

Individual faculty researchers are using the laboratory in several ways. Professor Rowell is setting up an experimental system to investigate ultrasonic imaging and reconstruction methods. He and a student have designed a computer driven ultrasonic data acquisition system that will allow for the investigation of three dimensional image reconstruction using transmission and reflection ultrasound. Professor Brownell uses his

well established laboratory at the MGH for the acquisition of PET scans. Similarly, magnetic resonance imaging systems in various collaborating laboratories are used as input to the facility. Professor Yanch is involved in research in both medical imaging and computational methods in radiation therapy with the main focus the simulation of radiation transport for a variety of applications.

A steering committee convened last year to consider the long-term mission of imaging and computations research at MIT continued to meet periodically throughout the year. The committee includes faculty and senior researchers from the Departments of Mechanical Engineering, Nuclear Engineering, the Division of Health Sciences and Technology, and the National Magnet Laboratory.

The Biomedical Imaging Sciences lecture series, sponsored by the College, was host to three renowned imaging scientists this year.

MEDICINAL CHEMISTRY AND CONTROLLED DRUG DELIVERY SYSTEMS

Research activities in Professor Robert Langer's laboratory continues in four major areas: (1) drug delivery systems (2) cell delivery systems; (3) drug removal systems using immobilized enzymes; and (4) studies on angiogenesis inhibition.

Some of his recent advances include the following: A drug delivery system using biodegradable polymers and developed by Prof. Langer's group is now being used in the treatment of over two hundred patients with brain tumors. The initial results indicate that life span is significantly increased when compared to conventional therapies. In the cell delivery system area, significant progress has been made by using polymers as novel carriers for delivering liver cells and cartilage cells. The hope is that this research could lead to a new approach in organ transplantation. In the area of drug removal systems important advances have been made in developing an immobilized, low-density lipoprotein (LDL)-cholesterol removal reactor. Studies *in vivo* as well as *in vitro* have shown that a novel immobilized enzyme reactor can remove cholesterol seventeen times faster than normal. Finally, Prof. Langer and his laboratory have purified and sequenced a substance from cartilage that causes inhibition of neovascularization.

Active in teaching both semesters, Prof. Langer and his colleagues also presented a one-week summer course in Controlled Drug Delivery Systems. He supervised sixteen graduate students this year representing the departments of Chemical Engineering, Chemistry, Material Sciences and Engineering, and the Division of Health Sciences and Technology. In addition, his laboratory includes ten undergraduates, eleven postdoctorals, two visiting scientists, and eight research staff.

Prof. Langer holds a secondary appointment in the Whitaker College, which houses his major laboratories; his primary appointment is in the Department of Chemical Engineering.

J. DAVID LITSTER

Department of Brain and Cognitive Sciences

Research in the Department of Brain and Cognitive Science integrates diverse approaches to the understanding of brain functions; provides a focus for collaborative efforts across disciplines at the Institute; and offers an opportunity for comprehensive and multidisciplinary training of new scientists. The faculty now includes 29 primary appointments, three joint secondary appointments, a large research staff, and 50 Postdoctoral Fellows and Associates.

In the Department of Brain and Cognitive Sciences, there are four primary areas of research: neurobiology, computational neuroscience, systems neuroscience, and cognitive science. Research in these areas is conducted by the faculty with their students and postdoctoral fellows. In addition, a new area of cognitive neuroscience is evolving within the Department as a logical outcome of interactions among the disciplines of cognitive science, neuroscience, and computer science.

The faculty's research is amplified by collaborative efforts with other departments and laboratories, such as the Department of Biology, the Department of Linguistics and Philosophy, the Departments of Mechanical and Electrical Engineering, the Artificial Intelligence Laboratory, the Research Laboratory of Electronics, and the Media Arts and Sciences Center. These efforts have expanded in the last year.

RESEARCH

Neurobiology

Faculty members in this area are involved in a variety of studies ranging from the development of neuronal morphology and connectivity to the cellular and molecular basis of behavior and neurochemistry.

With respect to the development of the nervous system, the faculty's efforts are proceeding along two lines. One line of research is focused on understanding how the diversity and specificity of individual neurons arise from the undifferentiated embryonal cells and how neurons are assembled at the right time and place during development to generate a properly functioning nervous system. The other line is directed at understanding the role of molecules such as the proteoglycans that are involved in the growth and the guidance of axons in the brain.

With respect to the molecular basis of behavior, research efforts using the **Drosophila** system are focused on understanding the biochemical mechanisms underlying learning and memory. The interesting finding is that **Drosophila** mutants which fail to learn or which forget rapidly have identifiable lesions in the second-messenger systems. It is conceivable that these molecular processes underlying learning and memory are conserved across species from flies to humans. Such a finding would have clear implications for mental health.

With respect to neurochemistry and neurotransmitters, a number of studies have focused on such important transmitters as acetylcholine, serotonin, and dopamine. Among the important recent discoveries achieved by the faculty of the Department of Brain and Cognitive

Sciences, I would like to mention the finding that there are specific

factors enhancing the vulnerability of dopamine-containing neurons in the brains of patients affected by Parkinson's disease. This insight may lead to new therapeutic strategies relevant to the treatment of this devastating disease. Studies have also shown that Alzheimer's disease is associated with accelerated breakdown of membranes in the cholinergic brain cells, which seem to be especially vulnerable in this disease as opposed to other brain diseases such as Down's Syndrome or Parkinson's disease.

Systems Neuroscience

Research in this area is focused on understanding the visual, the auditory, and the motor systems. Research on neurologically impaired patients, another important area of investigation, is conducted at the Clinical Research Center.

Studies of the visual system, which range from investigations of early visual processes to the study of higher visual functions, are conducted by a number of faculty members. With respect to early processing of visual information, our faculty has focused on the role of the parallel channels that originate from specific neurons of the retina. Because selective blocking of single channels is now possible, a series of physiological and psychophysical studies have been conducted. These studies are aimed at assessing which basic visual functions (such as color, brightness, contrast sensitivity, perception of movement, and stereopsis) are altered by the block.

With respect to higher visual functions, our faculty has investigated the role of the cortical areas involved in transferring visual information into the motor system. They have identified an important cortical area in the parietal lobe, responsible for transforming visual signals coded in retinal coordinates to coordinates of the desired location of the eyes in the head.

Other cortical areas involved in the processing of visual motion are also being investigated. Finally, the plasticity of the cortical neuronal machinery is being tested through an experimental rerouting of visual fibers into the auditory centers. The preliminary results indicate that the reinnervated "auditory" center can process visual information. In the auditory system, progress has been made in tracing the pathway connecting the peripheral sensory cells to the analyzing centers in the brain.

The motor system is also an area of intense investigation. The focus of these studies is to understand the neural and computational processes underlying arm trajectory planning and execution.

Computational Neuroscience

Faculty members have focused on the study of information-processing in the area of vision and motor control. Basic research activity during the past year has addressed issues ranging from studies of object recognition to computational models of visual motion perception, machine-vision projects, and motor learning. In addition, computational work has been directed at the characterization of biophysical mechanisms subserving the detection of motion by cells in the retina.

Cognitive Science

Cognitive Sciences is the study of intelligent biological systems as

exemplified principally by the human brain. Research in the Department is focused on psycholinguistics, visual perception and visual psychophysics, reasoning, memory, and human conceptual development. The faculty comprising this area collaborate with faculty from MIT's Center for Cognitive Science brings together this research and related work in linguistics, philosophy of mind, and computer science. This work has been expanded to include studies of the genetic and neural underpinnings of grammar.

Research over the last nine years has resulted in a comprehensive solution to a major problem in learning theory applied to language acquisition; i.e. how children acquire knowledge of the ways in which language expresses information about predicate-argument structure.

Two other major contributions have been made in this area: The sequential network architecture developed here has become a standard tool in the connectionist modeling literature. The network has been used in models of phenomena in music perception, grammatical inference, morphological development, and speech recognition.

A new approach to the study of motor learning, "forward modeling", designed to address problems with excess degrees of freedom and delayed feedback also appears to be quite promising.

McDonnell-Pew Center for Cognitive Neuroscience

The McDonnell-Pew Center awarded three predoctoral and five postdoctoral fellowships in its first year. Since then, the applicant pool doubled, and, in response to this, we decided to award six postdoctoral fellowships for the coming year. The focus of the Center for Cognitive Neuroscience is visual perception and motor control, with emphasis on four themes: 1) object and shape recognition; 2) spatial cognition; 3) motor planning, and 4) learning and memory. The Center facilitates collaborative work among faculty who are engaged in pioneering work in their respective areas. This spring, the Center's colloquium series, coordinated by the predoctoral and postdoctoral fellows, attracted eleven distinguished scientists from the United States and abroad. Two graduate courses (Computational Laboratory in Cognitive Science and Cerebral Cortex) were offered as part of the Center's program, and a new Sun Microsystems SPARCstation 2 was purchased which will support students' and fellows' research and course work, particularly in the laboratory work for the Cerebral Cortex course. The Sun system has been connected to MIT's Artificial Intelligence network so that students in the course may perform model simulations.

Lucille P. Markey Program in Neurobiology

Financial support from the Markey Charitable Trust enabled us to establish a state of the art facility for microscopic imaging technology and monoclonal antibody production under the supervision of a technician experienced in both microscopy and hybridoma research.

The Microscopy/Imaging part of the facility was built by adding on to an existing video microscopy workstation that could be used for time-lapse video microscopy, low light level fluorescence microscopy and simple image processing. The major additions were the purchase of a confocal scanning fluorescence microscope and a Silicon Graphics computer workstation. The confocal microscope uses a computer controlled laser beam to scan samples and record fluorescent emission. This makes

possible certain types of applications that could not be done at all before. In particular, the confocal permits one to "optically section", i.e., look deep within thick pieces of living or fixed tissue. The Silicon Graphics workstation is used in conjunction with the confocal microscope to generate 3-D reconstructions of optically sectioned samples. It can produce animations as well as 2-D and 3-D images.

New equipment for basic cell culturing, part of the hybridoma research, allows for the production and screening of monoclonal antibodies by different groups.

The award from the Markey foundation has also allowed the Department to grant two postdoctoral fellowships and sponsor a retreat on Cape Cod in June. A series of scientific meetings held at the retreat succeeded in bringing together investigators from several laboratories in the Departments of Brain and Cognitive Sciences and Biology who share an interest in neurobiological research, in order to foster greater collaboration and exchange information on the progress of their research.

EDUCATION

Postdoctoral

Postdoctoral applications continue to increase, fueled by the reputation of the Department for leading edge research. Over the past year, the postdoctoral population increased by eight percent. Fellowships are supported by a variety of sponsors, both federal and private.

Graduate

We recently reviewed our departmental training record and found that, since its founding as the Department of Psychology in 1965, Course IX has graduated 129 Ph.D.s, 49% of whom hold professorships and 28% of whom have pursued research careers in academic or government laboratories. Recent graduates are faring well: of seven doctoral degree recipients in the 90-91 academic year, two have accepted assistant professorships, and five have accepted postdoctoral fellowships.

The number of applications to the graduate program reached a record high of 193 for September 1991 admission. The entering class will number thirteen, plus two special students accepted under the arrangement with the International School of Advanced Studies in Trieste, Italy.

We have implemented the new courses, seminars and colloquium series that comprise the training program in cognitive neuroscience described last year. So far, three students have enrolled in the broad new program, and three additional students will enroll in September. There have been no other major changes in the graduate curriculum since last year.

Undergraduate

The undergraduate major in cognitive science maintains a steady level of enrollment, with 40 primary majors as of September 1990. In addition, we continue to participate in the Program in Psychology, attracting large numbers of students to our classes in introductory psychology, social psychology, and developmental psychology. Undergraduate participation in laboratory research projects continues to be strong.

We have created the position of Academic Officer in the Department and

named Professor Alan Hein to fulfill this new role beginning with the 91-92 academic year. We believe the department will greatly benefit from Prof. Hein's commitment to improving and expanding undergraduate education.

OTHER ACTIVITIES

The Department has continued to offer lunchtime seminars featuring speakers of national and international renown. These seminars have consistently been popular and well received. In addition, members of the Department acted as co-chairpersons and speakers at the Fall Neurobiotechnology Conference sponsored by Whitaker College and the Industrial Liaison Program.

FACULTY AWARDS AND ACTIVITIES

Individual members of the faculty have been extremely productive and have received recognition by the Institute and outside foundations.

Special Award

Michael Jordan - Presidential Young Investigator's Award from the
National Science Foundation

Richard Andersen - elected to the Board of Governors of the
International Neural Network Society

Ann Graybiel - elected member of the American Academy of Arts and
Sciences and the National Academy of Sciences

Mary Potter - elected Chair of the Psychonomic Society Board

EMILIO BIZZI, M.D.
Chairman

OVERVIEW

The Center has evolved as a dynamic research relationship among analytical chemists, toxicologists, and engineers interested in sources controls and environmental fate and transport of hazardous substances.

Together, toxicologists and analytical chemists have developed means to answer the question "What amounts and kinds of chemicals are actually getting into people?" We can now measure the ubiquitous aromatic amines and many polycyclic aromatic hydrocarbons as reaction products with hemoglobin in human blood samples. Our goal is to be able to measure and identify as yet unknown chemical trespassers by combinations of new separation technology and tandem mass spectrometry.

The Center's geneticists and oncologists in the Division of Toxicology work with single cell systems, rodent cancer models, and human blood samples. Our new technology, mutational spectrometry, has many uses in mechanistic studies, but in particular it allows us to seek answers to the question "Of the chemicals entering human bodies, which, if any, are responsible for causing significant amounts of genetic change, especially those changes leading to birth defects and cancer?"

The engineers are trying to design safer combustion and incineration systems or to characterize the many changes that chemicals undergo as they distribute in the environment. This cadre of environmental engineers make up the majority of Center faculty. Our goal is to devise means to reduce human exposure to actually harmful chemicals. Together with toxicologists and analytical chemists, the combustion engineers in the Department of Chemical Engineers have found the primary human mutagens produced by incomplete combustion products. Now, they are aiming at this same level of understanding of the related, but distinct, process of pyrolysis.

The civil engineers of the Parsons Laboratory for Water Resources and Environmental Engineering are collaborating to map the sources and movement in the surface and groundwater at a nearby aquifer — the Aberjona River Basin. Their work is the initial effort in a program to characterize the chemical exposure routes of the water, air and food in the population of 50,000 citizens, including our faculty who live in the Basin.

Basic molecular mechanisms, genetic cascades in chemical carcinogenesis, direct human measurements, and engineering for a better, more healthful environment are all subjects of study for Center faculty at MIT, Harvard, the University of North Carolina, Northeastern University, and the University of Michigan who are united in this major research activity. We hope that this President's Report reflects both our diversity of approaches and our unity of purpose in pursuing goals that have value only if we can make a significant contribution to improving public health.

CORE UNIT A: COMBUSTION AND INCINERATION RESEARCH

Associate Directors: Prof. John P. Longwell and Prof. Adel F. Sarofim

In the combustion process even simple fuels such as natural gas (methane) produce polycyclic aromatics, oxygenated compounds, and soot. Some of these are known to be mutagenic. While these intermediate products can also be burned, practical equipment allows escape of varying amounts into the atmosphere. The broad goal of Core A is to develop a quantitative understanding of mutagen formation and destruction during combustion of major fuels and to work with toxicologists toward an understanding of the relationship of these emissions to human health.

Incineration of waste material is increasing in importance and our program is being extended to deal with this process which also involves the presence of chlorine and other elements. One program has been funded as part of the Center's Superfund Hazardous Substances Basic Research program.

Basic Studies of Mutagen Formation on Combustion of Vaporizable Fuels

Prof. Jack B. Howard and Prof. John P. Longwell

The jet-stirred/plug flow reactor previously developed in this program was used to produce samples from ethylene combustion for chemical analysis and bioassay and to produce basic information on formation of mutagens in flames. The effect of adding naphthalene to the stirred reactor combustion products is being studied. A large increase in higher molecular weight aromatics and soot is observed; however, acetylene concentration does not change. The large increase in soot production at constant acetylene concentration shows that soot grows by aromatic addition. This is contrary to the commonly held view that soot grows by acetylene addition. While soot increases with reaction time in the plug flow section the polycyclic aromatics show little change. This is due to the rate of formation of a given species being approximately equal to its rate of conversion to soot or other aromatic species. Soot produced at long reaction times, therefore, has a larger ratio of soot/aromatics.

Studies of Mutagen and Carcinogen Formation by Pyrolysis of Solid Fuels

Prof. John P. Longwell and Prof. Adel F. Sarofim

Pyrolysis, thermal decomposition in the absence of oxygen, is the first step in the combustion of solid fuel. Experimental procedures are employed to generate tars by pyrolysis followed by additional exposure to high temperatures where extensive chemical conversion takes place and where mutagens and soot are generated. Experimental work on pyrolysis of wood and lignite coal has produced samples for chemical analysis and for mutagenicity testing. At the highest temperatures, where much of the tar has been converted to soot, the composition of the higher molecular weight fractions are remarkably similar for tars from both lignite and wood. The mutagens cyclopenta(cd)pyrene and benzo(a)pyrene are major constituents. These tars from high temperature pyrolysis were significantly mutagenic in both bacteria and human cell tests — as anticipated from their composition. Tars from low temperature pyrolysis, however, did not contain appreciable amounts of mutagenic polycyclic aromatics and did not show significant mutagenic activity.

Studies of Nitrogen-, Oxygen-, and Sulfur-Containing Polycyclic Hydrocarbons in Furnace Flames

Prof. JM Beér

Nitrogen-containing polycyclic aromatic compounds (PAC's) are bacterial mutagens that can be produced by a wide range of combustion devices. The combustion conditions leading to the formation of these species are little known. In an attempt to understand the effect of the presence of precursors upon the formation of such species and their biological activity, several flames were studied in which the concentration of NO_x and the composition of PAC's present in the flame were varied. Biological activity of samples collected from the flames revealed that although the PAC composition changed when the fuel type was varied, the mutagenic activity of the samples did not change. Moreover, it was observed that a high NO concentration in the flame can cause an increase in the mutagenic activity. It is planned that, in the remaining part of this year and the coming year, fractionation and analysis of N-containing hydrocarbons (including PAC's) will be carried out. Furthermore, samples from these runs will be submitted for biological testing to better characterize and understand the contribution of the N-containing hydrocarbons to the mutagenic activity of the samples.

Toxicity and Mutagenicity of Combustion Generated Aerosols

Prof. JF Elliot (deceased) and Prof. Adel F. Sarofim

Submicron inorganic and soot particles generated in combustion can serve as surfaces for condensation of mutagenic tars. These particles are thought to be important elements for transport of mutagens from the air to the human lung and digestive tract. In this program, well characterized soot or inorganic oxide particles are generated and contacted with the organic vapor of interest. The mutation of human lymphoblast cells is then studied by interacting them with a suspension of these particles which are small enough to be phagotized by the cells. Soot particles produced in a laminar premixed flame burner were found on collection to be coated by condensed tars, producing a surface area corresponding to the external dimensions of the soot particles. On removal of the tar by heating, significant internal surface

was exposed indicating that part of the tar is soaked into the soot particles. It was also found that addition of iron or manganese to the fuel results in a significant increase in soot and tar. In human cell tests of soot produced without the metal additives, the phagotized tar-soot combination is less mutagenic than the equivalent amount of tar in solution. The soot particles from which the tar was removed were not mutagenic.

Mutagen Formation During Pyrolysis and Oxidation of Liquid Wastes

Prof. János M. Beér and Prof. Adel F. Sarofim

The overall goal of this project is to provide chemical and toxicological characterization of products formed during incineration of liquid wastes. Ignition and combustion of drops of chlorine-containing liquids are being studied. It was found that increasing the chlorine content of liquid drops had an inhibiting effect on the minimum temperature at which ignition occurs. A kinetic model of these results is being developed. Mutagenicity of combustion products from these tests, studied in *S. typhimurium* cells showed little effect of blending 50% *o*-dichlorobenzene, ethylene dichloride, or trichloroethylene with toluene; however, the composition of the resulting chlorinated tars differed significantly from the tars from pure toluene where the usual fluoranthene, benzo(a)pyrene, and cyclopenta(cd)pyrene appear to account for the observed mutagenic activity.

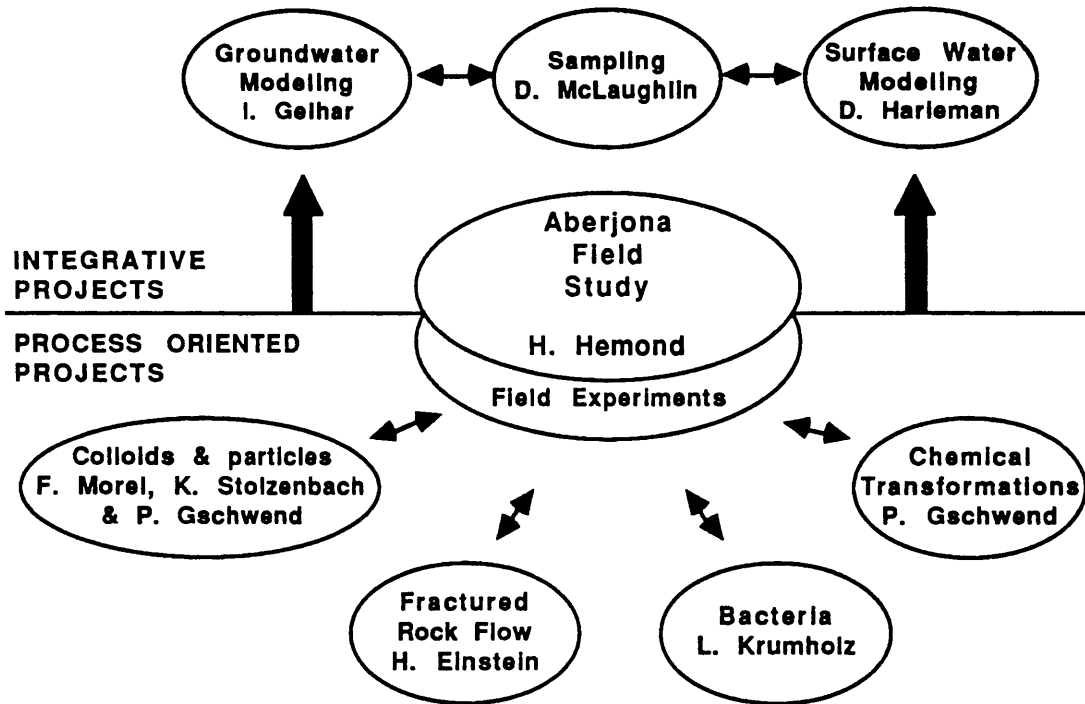
CORE UNIT B: ENVIRONMENTAL FATE AND TRANSPORT

Associate Director: Prof. François M.M. Morel

The activities of Core Unit B of the CEHS are focused on the issues of the environmental transport and transformation of hazardous pollutants. Specific research projects addressing fundamental scientific questions have been articulated around a central field project dealing with the movement of hazardous chemicals in the Aberjona Watershed northwest of Boston. At present, the field project has been funded through the NIEHS Superfund program and a specific project on bacterial mutational spectra in polluted aquifers has received funding from the EPA Northeast Hazardous Substances Center. Five other specific project proposals have been updated to obtain the necessary support. In addition, two projects have received seed funding from the CEHS.

The general objective of this section of the CEHS is a quantitative understanding of the degree of human exposure to hazardous waste. Our approach is to use a combination of mechanistic, process-oriented projects (chemical transformations, bacterial genetic markers, fractured rock flow, and transport by particles and colloids) and of integrative modelling projects (groundwater, surface water, and sampling strategies), all linked methodologically and thematically with the Aberjona field project (see Figure below). The field project provides a common focus and a means for articulation for the individual projects and insures the overall "relevancy" of the research. The individual projects amplify the field study beyond the particulars of the Aberjona Valley to provide results of general applicability at hazardous waste sites.

Led by Prof. Hemond, the Aberjona field project has now established the necessary background information regarding the sources and transport of hazardous chemicals in the watershed; historical documentary records, hydrologic monitoring, flow model, mutagenic activity and chemical reconnaissance, and sediment records. The field work will now focus on the identification of mutagens, the interpretation of the sedimentary record, and additional studies of ground to surface water transfer and source identification. In parallel, Prof. Chisholm will determine the variability in the 16 ribosomal RNA sequence of *Pseudomonas fluorescens*, using the protocol successfully developed in collaboration with Prof. Thilly.



Distribution and Movement of Water and Toxic Chemicals on the Aberjona Watershed

Principal Investigator: Prof. Harold F. Hemond

During the current budget period, research to develop essential background knowledge of the Aberjona watershed has continued. Chemicals which are believed to pose human health risks have been identified, and techniques for understanding the key environmental processes responsible for the movement of these chemicals are being explored. Highlights and specific accomplishments are as follows:

Industrial history: A historical investigation of the arsenical pesticide industry has begun. The largest arsenical pesticide manufacturer in the U.S. between 1899 and 1915 was located in North Woburn and may have contributed to the high levels of arsenic and lead found in the watershed.

Metals: A watershed-wide survey of metals contamination in sediments has revealed the wide spread distribution of higher-than-ambient levels of many metals such as zinc, copper, and lead, as well as "hotspots" which are severely contaminated with arsenic and chromium. Distributional patterns indicate that surface water transport of metals from source areas is responsible for elevated levels that can be found downstream. In addition, positive correlations between metal concentrations, organic carbon content, and decreasing particle size have been observed. Some of the highest levels of contamination have been found in lake and pond sediments, where core samples have been taken in order to geochronologically date metal deposition with the naturally occurring isotope, Pb^{210} . These studies will further our understanding of the mechanisms controlling the fate and transport of these metals. Results obtained to date correspond well to known industrial activities. Difficulties encountered during core sampling have led to the employment and improvement of an unusual technique used to freeze sediments *in situ*.

Volatiles: In addition to the reconnaissance of the volatiles in the surface water, a dual-tracer technique was used to identify chemical inflow in reaches of streams comprising the Aberjona watershed. The "east drainage ditch", Sweetwater Brook, the "landfill creek", Halls brook, and the northern part of the Aberjona River were studied by this method, and the areas of the chemical inflow were identified. The groundwater inflow rates of these flows were quantified, and rates per distance varied from 3.6×10^{-6}

L/m·s (essentially zero) to 3.1×10^{-1} L/m·s. Common volatile organic compounds in the inflow included 1,1,1,1-trichloroethane, trichloroethylene, and benzene, with concentrations in the inflow ranging from less than 1 $\mu\text{g/L}$ up to 120 $\mu\text{g/L}$. In addition to the identification of the inflow, surprising high rates of degradation of toluene have been found in the east drainage ditch, and it is suspected that biodegradation is the cause; its study will be continued.

Sediment transport: The ultimate goal of this study is to correlate the movement of sediments with the movement of contaminants in the Aberjona River. Currently, existing rainfall and stream-flow data are being reviewed to properly choose and develop a computer based hydrologic model for the watershed.

Mutagenic activity: During the last six months, progress has been made in assessing mutagenic activity in environmental samples from the Aberjona watershed. A sampling program was carried out in which 32 sediment samples were collected from sediment deposition areas in lakes, ponds, and streams. Extracts from each sediment sample were tested in both a bacterial and a human cell mutation assay. In the bacterial assay, point and frameshift mutations are measured in *Salmonella typhimurium* at the XPRT gene locus. The bacterial assays were conducted in both the presence and absence of an exogenous metabolizing enzyme system (PMS). In the human cell assay, point and frameshift mutations in lymphoblasts are measured at the TK gene locus. Results from the bacterial assays indicate that +PMS mutagenicity in sediment extracts is widespread in the watershed. Preliminary analyses of these results suggest that the +PMS activity may be correlated with the presence of chemical wastes (e.g., toxic metals) in the sediments. Human cell mutagenicity was detected in only two sediment extract samples. A retest of one of the extract samples that was mutagenic in the human cell assay confirms the initial result.

Research is now underway to isolate and identify the mutagens present in the sediment extracts. Progress has been made in fractionating whole extract samples to produce chemically distinct aliquots which are retested for mutagenicity. The immediate goal is to isolate the extract fraction(s) which account(s) for the majority of the total mutagenicity. Once the mutagenic fraction(s) have been isolated, work will begin on chemically identifying the mutagens.

CORE UNIT C: ANALYTICAL CHEMISTRY

Associate Director: Prof. Klaus Biemann

In the Analytical Chemistry area, the following three topics are being investigated: 1) The analysis of samples from the wide variety of combustion products generated by the projects is one major task. It involves both conventional and new methodology that is being developed and includes an extended effort to generate a permanent data base for the results. 2) The development of new technologies to identify biological sinks for extraneous chemical entities of health related significance and present at a trace level in physiological fluids, such as blood. Major emphasis is on the identification of adducts to hemoglobin. This requires the isolation of minute amounts of modified peptides in a complex mixture. And, 3) a survey of semi-volatile hazardous organic chemicals with an emphasis on chronology in an abandoned waste site.

In area 1, progress has been made in the analysis of large polycyclic aromatic compounds (PAC's) by improved chromatographic techniques, coupled with the development of a method of quantitation (by UV absorbance) for compounds where no standards exist (a common problem with compounds of increasing complexity). This methodology revealed the presence, in various combustion products, of PAC's consisting of up to ten fused rings. In addition, an effort has been started to gather all the analytical data obtained with each sample in a computer accessible form to facilitate correlation and optimal interpretation.

Progress in area 3 involves the development of methods for the enrichment of the modified section of the hemoglobin molecule. Presently, we are carrying out experiments that exploit the blocking of the action of exopeptidases by modified amino acids. We have found that certain aminopeptidases do not cleave at cysteine that has been ethylpyridinylated, which suggests that adducts of the size of ethylpyridine (and larger) can be enriched. Since the first cysteine of the hemoglobin β -chain is in

position 93, direct digestion of the intact protein is not practical. We therefore digest first with Endo-Glu-C, and then treat the mixture of peptides with aminopeptidase. Unaltered hemoglobin β -chain is expected to be completely degraded to free amino acids, while the Cys-93 ethylpyridinylated protein would give a residual peptide, 93-100, derived from the proteolytic peptide, 91-100, that contains the obstacle at position 93. This is indeed the case, but there are a few other peptidic components left, due to slow cleavage at other positions. Presently, we are investigating proteolysis conditions that completely degrade all peptide bonds, other than those involving the modified cysteines.

The work in area 3 centered chiefly on the chronological correlation of organic compounds found in vertical core samples taken at sites in the Aberjona River/Upper Mystic Lake region. The time period from 1930 to the present can be mapped and is correlated with the major waste materials disposed during this time period. It clearly shows the preponderance of hydrocarbons prior to 1940 and the appearance of chlorinated pesticides beginning around 1960. Core samples are also being tested for mutagenicity.

Future work in area 1 will continue the development and application of improved quantitation methods, particularly their expansion to the measurement of nitroarenes, and the use of more widely applicable column materials for HPLC. For area 2, both chemical cleavage at cysteine and blocking of endopeptidase action by bulky cysteine adducts will be further investigated, along with improvements in the mass spectrometric detection of the resulting materials. The coring and analysis work for area 3 will be expanded to the point that enough data are obtained for comprehensive interpretations.

Analytical Chemistry: General Methods for Determination of Human Hemoglobin Adducts

Principle Investigator: Prof. Klaus Biemann

Objectives

To develop and improve the identification of the components of complex mixtures of polar organic compounds by high performance liquid chromatography (HPLC) directly coupled with tandem mass spectrometry (MS/MS).

Approach

Since the most difficult task in the direct measurement of tandem mass spectra on the effluent from an HPLC is proper timing of the concerted operation of the two mass spectrometers (MS-1 and MS-2), we are developing a linked control system for the two instruments. This requires the development of a strategy involving the pre-programming of the choice of the mass of the precursor ions (protonated molecules of the eluting species) to be selected by MS-1, and then scanning MS-2 appropriately at the right time. The linked scan of MS-2 is not a trivial matter but can be achieved through proper software. Since the scan speed must be increased without loss of sensitivity, an array detector is used to record the resulting spectra.

Relevance to Human Health

The ability to obtain mass spectral information on the components of polar mixtures -- ranging from polar metabolites of xenobiotics to peptides (even if modified) generated by cleavage of proteins -- is clearly important for the determination of biologically significant molecules.

Accomplishments

We have designed, constructed, and tested an integrated HPLC-MS/MS system aimed towards convenient, reliable, and efficient use. The major new components involve the construction of a vacuum lock for the interface (Frit-FAB) that allows attachment and removal of the HPLC without breaking the vacuum. This change not only makes it easier to switch from batch operation to HPLC operation, but also reduces contamination of the ion source while not actually using the HPLC as a separation and sample introduction device.

In order to make the recording of MS and MS/MS spectra of consecutively eluting fractions practical and efficient, we have placed both mass spectrometers of the tandem instrument under computer control. This permits injection of a small aliquot of the sample mixture for the determination of the molecular weights of all eluting components. With this information in hand, it is then possible to program the first mass spectrometer to jump one $(M + H)^+$ ion to the next, for each consecutively eluting component of a larger aliquot injected. The second mass spectrometer is then scanned appropriately to record the corresponding fragment ions resulting from gas collisions in the interface region between the two instruments.

We have greatly improved the array detector for the second mass spectrometer of the tandem system. The addition of a quadrupole lens assembly permits varying the dispersion of the ion beam and thus the mass range that can be focused simultaneously onto the 54 mm long detector. This arrangement extends the 6% range of the earlier version to 30% and thus either increases the speed with which a spectrum can be recorded or decreases the amount of sample required to obtain a spectrum of the same quality, each by a factor of five.

Future Directions

We are planning to automate the instrument control, data acquisition, and data processing to minimize sample consumption. Since the experiment is "driven" by the speed of elution of the components from the HPLC, the timing of all steps is crucial to avoid missing a component, which would require re-injection of a further aliquot of sample that may not even be available.

CORE UNIT D: BIOCHEMISTRY, GENETICS, AND TOXICOLOGY

Associate Director: Prof. Steven R. Tannenbaum

Within Core D are several activities: development of technology for direct human measurements, study of the carcinogenic process in animals and mechanistic studies of chemical and radiation effects in bacteria, yeasts, rodent, and human cells and animals.

The faculty represent the research areas whose integration is necessary for a meaningful public health perspective. Professors Deen, Marletta, and Tannenbaum investigate the pharmacokinetics and metabolism of environmental toxicants especially nitrosamines, polycyclic hydrocarbons, aromatic amines, and natural products. Dr. Dasari and Professors Tannenbaum, Thilly, and Wogan together with Professor Biemann (Core C) are allied in developing new technology to measure chemicals and mutational spectra directly in human blood and tissue samples. Professors Tannenbaum, Thilly, Wogan, and Zarbl are tightly linked in dissecting the relationships among protein adducts, DNA adduct among and sequence positions, mutational spectra, especially in oncogenes, and discovery of the oncogene and suppressor genes at risk in animal chemical core models. Emphasis on food-borne toxicants such as aflatoxin B₁ and urethane are a mark of this collaboration. A closely interacting group of molecular geneticists, Professors Demple, Essigmann, Samson, Thilly, Walker, and Zarbl share their strategies to identify and understand the enzymatic steps in the pathways that separate DNA adducts from mutation in microbial and mammalian cells.

In the coming year the Core D faculty look forward to progress both in studies of basic mechanisms and in gaining useful facts about human exposure and mutation. We have achieved a synthesis of the "pure and applied" and hope that both areas of our endeavors may serve the public good.

Advances in 1990 include:

1. Increased sensitivity of tandem mass spectrometry for detecting and measuring human hemoglobin adducts of unknown structure. Prof. Biemann's combination of MS-MS hardware with charge-coupled device detectors has resulted in several order of magnitude increase in sensitivity and is drawing close to the technical goal of 1 μg unknown adduct per gram of human hemoglobin.

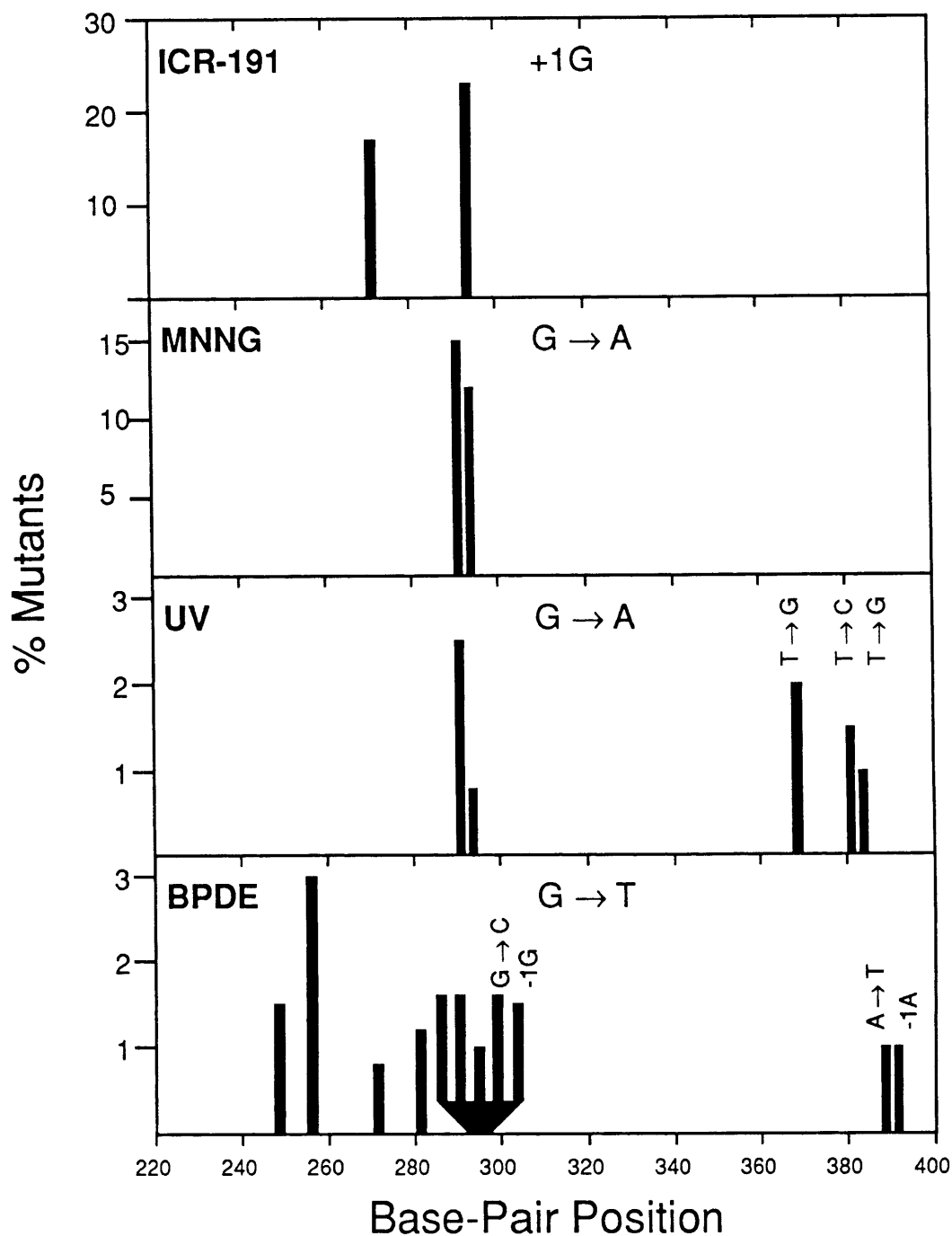


Figure 2: Point Mutational Spectra in Exon 3 of the Human HPRT Gene for Four Separate Mutagens

2. Prof. Tannenbaum and Dr. Dasari have achieved first measurement of polycyclic aromatic hydrocarbon–human hemoglobin adducts in blood samples of ordinary citizens. This marks the first time that direct chemical dosimetry of reactive PAH's has been possible in humans.

3. Dr. Keohavong and Prof. Thilly have made crucial advances in analysis of mutations in humans. They have found means to use a thermostable DNA polymerase to amplify human DNA sequences with high fidelity, a process necessary for observing the mutations which exist in ordinary human tissue samples. Furthermore, they have, for the first time, characterized the mutational spectra of a series of environmental mutagens in human cells. Spontaneous mutation, oxygen, ultraviolet light, an alkylating agent, and an active metabolite of benzo(a)pyrene have all been so characterized. Examples of the information now available from direct human cell measurements are shown in the accompanying figure.

WILLIAM G. THILLY

Division of Toxicology

The Division of Toxicology was established as an administrative unit within the Whitaker College of Health Sciences and Technology in order to maintain the integrity and momentum of the programs offered by its faculty in an optimal setting for fruitful research and teaching interactions. These programs are fully operational in this administrative setting, and some pertinent aspects concerning their objectives and structures are summarized below.

FACULTY

Faculty members whose primary academic affiliations are in the Division include Professors John M. Essigmann, Steven R. Tannenbaum, William G. Thilly, Gerald N. Wogan, and Helmut Zarbl. A final candidate has been identified for a new faculty position as Assistant Professor of Toxicology, to whom an offer of appointment is currently outstanding. It is anticipated that the appointment will become effective on September, 1991. Appointment of an additional faculty member has recently been authorized, and a search for candidates is being initiated. Candidates with backgrounds in mechanisms of microbial pathogenesis, whose research interests will complement those of current faculty in both Toxicology and Comparative Medicine are being sought. Professor James G. Fox, director of the Division of Comparative Medicine also holds a secondary appointment in the Division of Toxicology. Professors Essigmann, Tannenbaum and Wogan hold joint appointments in the Department of Chemistry, and Professor Thilly in the Department of Civil Engineering.

EDUCATIONAL PROGRAM

The major educational activity of the Division is the operation of a graduate degree program leading to SM/PhD degrees in toxicology. In its teaching and research endeavors, the program is focused on understanding how the interactions of organisms, including humans, with chemical and physical agents in the environment induce toxicity and pathogenesis, with the goal of elucidating the origins of cancer and other genetically-linked diseases in humans. The program requires thorough undergraduate backgrounds in chemistry or biology. Emphasis is placed on thorough knowledge of biochemistry, genetics, molecular biology and toxicology, together with the development of research approaches to current problems in environmental health sciences, utilizing the methods and logic of molecular biology and biochemistry.

Although no undergraduate major is offered in toxicology, faculty of the Division play active roles in undergraduate education through teaching of undergraduate subjects, supervision of undergraduate thesis research, UROP projects, IAP activities, and advising of undergraduate majors in other academic Departments.

With the formation of the Division of Toxicology as a unit of Whitaker College, the educational programs in which the Toxicology faculty members participate were also formally transferred to the College. As indicated above, these consist primarily of graduate degree programs leading to doctoral and master's degrees in Toxicology. These programs represent modifications of the Toxicology area of specialization formerly offered in the Department of Applied Biological Sciences. Although that area of specialization was formally established in 1975, the earliest degree with a specialization in Toxicology was awarded in 1963. Between that time and the present, a total of 98 degrees in Toxicology have been awarded, 66 at the PhD level, and 32 at the SM level. Records of immediate postdoctoral employment for degree recipients indicate the following distribution: academic positions, 68%; industrial positions, 16%; government positions, 12%; and others, e.g., consulting firms, self-employment, etc., 4%.

Over the past decade, the average number of doctoral candidates in Toxicology was 30 to 35. Although the enrollment declined to its current level of 25 as a consequence of the administrative relocation of the Division, full complements of new students entered the program in the 1988-90 and 1990-91 academic years, and six students have been admitted for the 1991-92 academic year. Plans for the future are to admit six to eight new students each year, and the total number of doctoral candidates is expected to increase to previous levels. In addition to Toxicology majors, members of

the Toxicology faculty also currently supervise thesis research of 8 doctoral students in Chemistry and Applied Biological Sciences, and thus the total commitment is to 33 graduate students.

In its teaching and research endeavors, the Toxicology degree program is focused on understanding how the interactions of organisms with chemical and physical agents in the environment induce toxicity and pathogenesis, with the goal of elucidating the origins of genetic and related diseases in humans. The degree program represents an interface between programs of the Departments of Chemistry and Biology in the School of Science; the Departments of Chemical, Civil and Nuclear Engineering in the School of Engineering; and other units of the Institute such as the Energy Laboratory. In this position, it plays a pivotal role in fostering the development of interdisciplinary research programs among a variety of laboratories. Interactions of members of the Division with colleagues in other units of MIT are discussed further below.

The curriculum of the program is designed to provide rigorous training in the basic sciences, with particular emphasis on chemistry, biochemistry, molecular biology, genetics and toxicology. Students receive preparation for careers involving the application of modern methods of chemical, molecular biological and genetic analysis to research related to risk assessment in the chemical, biotechnology, pharmaceutical, and food industries, as well as in governmental regulatory and research agencies.

Students admitted into the degree program pursue a series of required and elective subjects that ordinarily require three semesters to complete. Following successful completion of a written comprehensive examination, usually administered in the fourth term of study, students must submit and defend a thesis proposal not later than three semesters later. Presentation and defense of the thesis proposal to a thesis committee constitutes the oral portion of the doctoral examination. A minimum of two progress reports on research leading to the doctoral thesis must be presented to the thesis committee prior to submission of the thesis. In all, completion of the doctoral requirements takes an average of five years.

RESEARCH AND TEACHING INTERACTIONS

Relationships between members of the Division of Toxicology and other units of MIT as well as various industrial and other organizations take many forms. The scale on which such interactions take place ranges from collaboration between two individual faculty members to large-scale research consortia which involve numerous participants at various levels. The following summary will serve to illustrate the character of some of these interactions.

Many interactions take place between members of the Division and those of other departments within the School of Science and also across School lines, in particular with the School of Engineering. Examples of both joint efforts in teaching and research can be cited, but those relating to research collaborations are particularly noteworthy. Within the School of Science, many joint endeavors with members of the Department of Chemistry exist. Some current examples include: mechanisms of action of the antitumor agent cis-platin (Essigmann and Lippard); isolation and characterization of carcinogens (Wogan, Tannenbaum, Buchi and Berchtold); and characterization of metabolites and mechanisms of action of mycotoxins (Wogan, Tannenbaum and Buchi). Many other specific examples of research collaborations could be listed, but the above projects serve to illustrate the point that interactions with Chemistry are extensive. Interactions with members of the Biology Department also take place, an example of which is the study of mechanisms of mutation (Essigmann and Walker). In addition, a Specialized Center of Research Excellence for the study of genetic toxicology was established by NIH, the members of which are Profs. Thilly (Director), Walker (Biology), Demple (Harvard) and Samson (Harvard).

Several types of joint educational activities as well as research also take place within the School of Science and the School of Engineering. A very extensive current research collaboration is that involved in the Center for Environmental Health Science. Faculty members of the Division of Toxicology also form the nucleus of the Center for Environmental Health Sciences, and include Profs. Essigmann, Fox, Tannenbaum, Thilly, Wogan, and Zarbl. Prof. Thilly is Director of the Center. The Center was established at MIT in 1978 with funding provided by the National Institute of Environmental Health Sciences (NIEHS), and has the objective of conducting a comprehensive program of research on the health effects of fossil fuels utilization. Research programs carried out

under the auspices of the Center are broad, interdisciplinary programs involving participation by members of the Division of Toxicology, and the Departments of Chemistry, Chemical Engineering, Materials Sciences and Engineering, and the Energy Laboratory.

The programs are intended to characterize the extent and mechanisms of formation of emission products generated by a variety of established and novel combustion processes and to evaluate these products for potential carcinogenic or mutagenic properties. Having developed an understanding of the manner in which combustion of fuels of a variety of compositions under controlled conditions gives rise to carcinogenic or mutagenic emission products, including the thermochemical and physicochemical factors that determine the nature of the products formed, the ultimate goal is to develop control methods for minimizing emission of the most hazardous products. The outstanding feature of this integrated program is the close collaboration that takes place among experts in combustion science and engineering, the biological sciences, and the physical sciences. These collaborations involve not only faculty and research staff members, but also graduate students and undergraduates as well, and the program has been well received by participants and supporting agencies.

The programs of the Center for Environmental Health Sciences were expanded in September, 1987, by the award of new funding for research into methodology for detecting possible health impacts of toxic wastes that contaminate various environmental media. The funds, provided through the Superfund legislation and administered by the National Institute of Environmental Health Sciences, support work of Profs. Thilly and Tannenbaum of the Division of Toxicology, Prof. Biemann in Chemistry, and Dr. R. Desari of the Laser Spectroscopy Laboratory. It is anticipated that the initial scope of the program will be substantially expanded in the near future through additional projects directed by faculty members of the Departments of Chemical Engineering and Civil Engineering.

HONORS AND AWARDS

The following honors and awards were accorded to faculty and students of the Division during the current academic year.

Prof. John M. Essigmann was awarded an Outstanding Investigator Grant by the National Cancer Institute, NIH. Funds from the grant will support the work of Prof. Essigmann's research group for a seven year period.

Prof. James G. Fox was awarded the American Veterinary Medical Association's Charles River Prize in Laboratory Animal Science.

Mr. Donald Brunson and Ms. LaCries Kidd were awarded fellowships by the Minorities Access to Research Careers program of the National Institutes of Health.

The M. M. Znaty Award for Graduate Research was presented to Ms. Hoonjeong Kwon in recognition of her doctoral thesis research with Prof. S. R. Tannenbaum.

Ms. Hilary Coller was one of three MIT students selected as recipients of the Clare Booth Luce Fellowship to support women graduate students in engineering and science.

GERALD N. WOGAN

CHAIR OF THE FACULTY

THE FACULTY POLICY COMMITTEE

This year the Faculty Policy Committee (FPC) divided its time between guiding various issues and legislation to the Faculty for discussion and participating in the Institute's efforts to set goals and priorities for the future.

The FPC conducted an ongoing dialogue about the appropriate role the Faculty should play as the Institute undertakes a long-range planning process. These discussions covered many topics, such as: the usefulness of the faculty meeting as a form of governance; increasing congressional and public cynicism about research universities; collegiality and mentoring among faculty; funding inequities among MIT Schools and departments; the use and allocation of laboratory space; gender and diversity concerns; students' diminishing interest in academia as a career; and the rigor of the tenure track and its impact on family and work issues. The FPC expects to continue addressing these issues in coming years.

The FPC heard from committees and individuals also working to hone and define MIT's institutional perspective on a variety of levels:

- President Charles M. Vest participated in Committee discussions about faculty governance and the dynamics of faculty-administration relations. The discussions included characterizations of collegiality at MIT, the role of the Chair of the Faculty, and ways to encourage greater faculty participation in faculty meetings and on committees.
- The MIT Committee on ROTC discussed its recommendations with the FPC before presenting them to the Faculty in October. The Faculty passed a motion calling for ongoing initiatives to change the Department of Defense policy regarding sexual orientation, and for MIT to consider terminating ROTC on campus if satisfactory progress on this issue is not made by 1998.
- Professor Eugene B. Skolnikoff, chair of the Faculty Study Group on the International Relations of MIT, updated the FPC on his group's report. The Study Group saw MIT's broad and open links with the international science and technology community as crucial to its ability to serve American society and recommended that MIT continue these diverse links while strengthening and expanding its research and educational programs in support of American industry.
- The Committee on Academic Computation for the 1990s and Beyond (CAC) presented the results of fourteen months of deliberations. CAC's recommendations sought to keep MIT at the forefront of academic computing while keeping costs at a manageable level.
- The report of the Committee on Sexual Harassment generated several FPC discussions during the year. The report recommended a new Institute policy on harassment, which was discussed by the FPC and taken to the Faculty as an informational item. This presentation generated faculty concerns about free speech issues and resulted in a review by the Committee on Faculty-Administration (CFA). The CFA made preliminary recommendations and will continue to deliberate these issues next year.
- As part of its effort to be informed about activities in the five Schools, the FPC met with Dean Lester C. Thurow of the Sloan School. Dean Thurow raised several issues: a perceived shift in faculty loyalty from an institutional to a professional focus, competition for faculty among the nation's business schools, and perspectives on the academic and financial structure of the Institute.
- Dean John P. de Monchaux updated the FPC on activities in the School of Architecture and Planning. He touched on issues specific to his School and also addressed concerns about its larger role in Institute initiatives. Among the topics raised were: the upcoming reviews of the Media Arts and

Science Section and the Departments of Urban Planning, problems of scarce research support and financial aid for students and faculty, and the role that the School could play in MIT's actions on environmental, economic, and public awareness issues.

- The FPC followed campus events related to the Gulf War, in particular, MIT's Community Series on the Middle East. The series featured MIT Professors Lincoln P. Bloomfield and Charles Stewart III, and Dr. Walid Khalidi, a visiting scholar at Harvard's Center for Middle Eastern Studies.

The FPC's discussions of governance issues resulted in changes to faculty procedures:

- The FPC followed closely the deliberations of the Study Panel on Demonstrations. The Faculty voted to create the Panel in Spring 1990. Professor John G. Kassakian, chair of the Study Panel and a member of the FPC, discussed the Panel's final report and policy recommendations. The report recommended that the Chair of the Faculty appoint an ad hoc committee to oversee events, at his or her discretion, when demonstrations become the focus of confrontation on campus. The report was presented to and endorsed by the Faculty in its May meeting.
- The Committee devoted much time to discussing procedures governing student appointments to committees. Students voiced a need for greater control over committee appointments, including the power to remove student members who fail to keep fellow students informed of committee activities. The Committee emphasized its confidence in existing faculty policies and procedures and in the ability of committee chairs to make appointments in conjunction with student leaders. The FPC also reiterated its belief that committee membership is an act of individual participation and that students should not be required to tailor their participation to the needs of specific constituencies.
- At the request of the Graduate Student Council (GSC), the FPC presented a motion to the Faculty requesting speaking privileges for the vice president of the GSC. The Faculty voted to change section 1.32 of the *Rules of the Faculty*, to permit the President and Vice President of both the Undergraduate Association and the Graduate Student Council to speak at faculty meetings.
- The Committee undertook a review of the list of ex officio members of the MIT Faculty. After much discussion, the FPC and the Officers of the Faculty decided to cease conferring ex officio status and to allow the current list to shrink through attrition. The FPC will continue to discuss this topic next year to devise alternative means of including key administrative staff in faculty meeting discussions.

The FPC continued its stewardship of academic policy matters:

- The Committee on the Undergraduate Program and the Committee on the Science Requirement kept the FPC informed of their progress in organizing the implementation of an Institute requirement in biology. The Faculty passed legislation describing the core biology subject in May. The motion included a mandate for a committee to review the General Institute Requirements and the academic calendar. The FPC will follow the deliberations of the new committee in the coming year.
- The Committee reviewed final changes to the *Rules of the Faculty* on grading issues. The motion passed in November redefined the P grade as the equivalent of work at the level of C or better, effective for all students in 1992.
- The Committee approved final revisions to the Rules and Regulations of the Committee on Discipline (COD). The changes were based on recommendations made by an FPC subcommittee last year. The Faculty subsequently revised the Rules of the Faculty to permit former COD members to participate in hearings when the Committee's workload is particularly heavy.
- The FPC reviewed the Committee on Student Affairs' (CSA) recommendation that MIT strengthen its ties with campus religious organizations. These discussions resulted in additional attention being given to the relationship between MIT chaplains and the Office of the Dean for Student Affairs. The

Committee also discussed the possibility of an Institute committee on the chaplaincy, but did not reach agreement on the advisability of this suggestion from the CSA.

- At the request of the Committee on Academic Performance, the FPC clarified its interpretation of the Faculty rules regarding evening exams and the freshman credit limit.

Finally, the FPC reviewed some issues that will figure prominently in future years:

- Dean of the Graduate School Frank Perkins visited the FPC twice to discuss matters of importance to graduate students. Financial concerns dominated both discussions as rising health insurance premiums, possible NSF grant reductions, and expected reductions in overhead rates threatened graduate student tuition and stipend funds.
- Provost Mark Wrighton presented faculty retirement concerns. He outlined possible procedures and financial packages that will meet the needs of the faculty when the mandatory retirement age is abolished in 1993.
- The Committee addressed issues of possible representation on faculty committees for postdoctoral fellows and associates (postdocs) but did not recommend any changes at this time. The Committee discussed ways in which the Institute might help incoming postdocs assimilate to MIT, including more centralized administrative support for postdocs as a group and explicit guidelines for postdoctoral appointments and research.

Professor Jacoby expressed his deep appreciation to all FPC members for their hard work this year and especially those leaving the Committee: Professors Lotte Bailyn and Mary Lou Pardue, Ms. Paula T. Hammond and Mr. Andrew P. Strehle (graduate and undergraduate student members, respectively). The Committee bid a fond farewell to Professor Jacoby as he completed his term as Chair of the FPC and applauded his tireless efforts as Chair of the MIT Faculty.

THE COMMITTEE ON THE UNDERGRADUATE PROGRAM

The Committee on the Undergraduate Program (CUP) saw several ongoing initiatives through to completion this year. The CUP and the Committee on the Science Requirement (CSR) presented a motion to the Faculty to implement a core Institute Requirement in Biology, beginning in the fall of 1993. Led by Professor Thomas Greytak, with the cooperation and initiative of the Department of Biology, the CSR (established in the 1989 motion recommending the Biology Requirement) examined the implementation question and brought its proposal to the CUP's 1991 January Work Session. Throughout the spring, the CUP and the CSR worked together to craft the motion passed at the May Faculty Meeting which included the following provisions:

- The Biology Requirement will be satisfied by a single subject based on modern molecular biology, labeled 7.01n. This subject will be offered in several versions (7.011, 7.012, etc.), with each version having a similar core but emphasizing a different aspect or application of biology for students with differing backgrounds and interests.
- Also effective in 1993, the name of the Science Distribution will be changed to Restricted Electives in Science and Technology. To make room for the requirement in the curriculum, the number of subjects required in Restricted Electives in Science and Technology will be reduced from three to two; both of these may be specified by departmental programs, but no more than one may lie inside the department.
- An ad hoc committee appointed by the President will be formed to review the scope and balance of the General Institute Requirements as well as the Institute calendar and its implications for the academic program. The committee will report its initial findings to the Faculty during the 1991-92 academic year.

The CUP also concluded its work on grading changes voted by the Faculty in 1989. The subcommittee on pass/fail assembled the final motion to implement the grading changes for juniors and seniors. The changes voted by the Faculty in November revised the *Rules and Regulations of the Faculty* to implement the P/D/F grading system for juniors and seniors in pass/fail subjects, effective in the Fall of 1992. The CUP also reviewed freshman performance during Fall 1990, the first term in which freshman subjects were graded under a system where a passing grade is given for performance at a level of C or better.

The Committee monitored several experimental projects, including: revisions to the freshman evaluation process, procedures dealing with transfer students, a pilot study of how students allocate their study time, a new early warning system for freshmen in science core courses, and a math diagnostic test for entering freshmen.

The CUP requested reports from several committees and individuals throughout the year:

- President Charles Vest visited the CUP to address issues affecting undergraduate education, including: the impact of student life issues on the undergraduate program, the necessity of a robust education that enables students to learn and evolve with rapid changes in national and international contexts, and the need to bridge the cultural boundaries between students and faculty.
- The Integrated Studies Program (ISP) review committee, chaired by Professor Anthony French, submitted its report recommending that ISP become a permanent component of the undergraduate program. The CUP endorsed the report which included several other recommendations regarding ISP.
- The IAP Policy Committee informed the CUP of its efforts to bolster faculty participation in teaching IAP courses, increase the number of credit-bearing activities, and facilitate the transfer of responsibility for organizing IAP offerings to academic departments.
- Leaders of the Undergraduate Association and the Student Committee on Educational Policy presented issues of particular importance to undergraduates, such as calendar and IAP concerns, HASS-D finals, the Writing Requirement, and diversity issues.
- Professor Sheila Widnall, Chair of the Committee on Discipline, visited the CUP to address issues of academic honesty. The discussion revealed concerns about the risks students assume when they cheat. Several recommendations were made about ways to handle cheating at MIT.
- The Committee discussed issues affecting engineering education, including increased emphasis on teaching techniques, mentoring of engineering students and faculty, accreditation issues, and various proposals for five-year degree programs.
- Associate Provost for the Arts Ellen T. Harris reported on the various academic and community initiatives sponsored by her office.
- The CUP made its annual examination of the Educational Commons, noting that the continuing study of participation in commons activities has been helpful in gaining recognition for faculty participants. The report has also proven useful to departments when formulating five-year plans.
- The CUP also reviewed the reports of the Committee on Academic Computation, the MIT Committee on Sexual Harassment, and the MIT Committee on ROTC.

The CUP bid farewell to departing members Professors Anthony French, Travis Merritt, William Siebert, J. Kim Vandiver, and David Wormley, Ms. Norma McGavern, and Messrs. Riad Bsaibes and William Buckner (undergraduate student members). Special thanks were extended to Professor Vandiver for serving as Deputy Chair of the Committee this year.

OTHER FACULTY COMMITTEE REPORTS

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year:

Most of the efforts of the **Committee on Academic Performance (CAP)** were devoted to its line responsibility to review records of students with poor grades or insufficient progress toward a degree and considering petitions for variations in the rules. In addition, the CAP considered several policy issues. At the start of the spring term, the long-awaited policy on evening examinations was finally promulgated. Difficulties in that policy arose quickly, and a minor modification to the policy was made after discussions with the Faculty Policy Committee and the Committee on the Undergraduate Program. Primarily, this modification accepted the practice of holding examinations during back-to-back 5:00-7:00 p.m. and 7:00-9:00 p.m. time slots.

The CAP worked toward developing a policy for handling petitions for extensions to the freshman credit limit. That policy is not complete but will likely include *no* extensions during the first term and only *minor* extensions during the second term for *well-documented cases*. It is also the feeling of the committee that there should be an orderly way for students with substantial advanced placement credit to become sophomores at the end of their first term. The CAP discussed with the FPC and the CUP the possibility of restricting freshmen to four major subjects plus one seminar, not to exceed 54 units in the fall term and 57 units in the spring, but it was determined that the CAP does not have the authority to impose this limit.

CAP has requested a review of the "performance" subjects because of the suggestion by several first-year students, in petitions to exceed the freshman credit limit, that there is no substantive difference between the requirements for credit and participation in the equivalent performance activity as an extracurricular activity. The Committee on Curricula has promised to complete this review some time during the Fall 1991 term.

Finally, in conjunction with the Undergraduate Academic Support Office, the CAP attempted to formulate orderly ways of handling first-year students with unsatisfactory academic records. This has become a key question with the decision of the Faculty to consider the D grade as a failure. Reasonably firm guidelines were developed and sent to freshman advisors at the ends of the fall and spring terms, and were used as the criteria for end-of-term decision meetings.

The **Committee on Corporate Relations** serves as advisor to the administration regarding MIT's interactions with national and international corporations. The Committee is particularly concerned with faculty perspectives in regard to research policy issues. One important issue that the Committee has considered this year is the potential conflict between the interests of various sponsors and international economic competition. The Committee has worked closely with other Institute committees to develop a full understanding of the range of concerns.

The Committee has also invested considerable effort in exploring mechanisms for increasing industrial interest in MIT research via improved communication between faculty members and corporations. The Office of Corporate Relations represents an important asset in enhancing such opportunities. In particular, the Corporate Relations staff has close ties with individual Industrial Liaison member companies. Their knowledge can be used to assist faculty, particularly junior faculty, in matching industrial research and development needs with MIT capabilities.

The chief duty of the **Committee On Curricula (COC)** is to assure that a diverse group of faculty exercises oversight on a number of classes of administrative transactions concerning the *MIT Bulletin* and the details of credit allocation for specific course subjects.

The Committee spent the majority of its meetings assessing proposals for new, changed, or deleted subject offerings; reviewing changes to undergraduate curricula submitted by the academic departments; and responding to student petitions for substitutions and variances regarding the General Institute Requirements for degrees. For the former, the COC worked to assure that the subject description promised an appropriate amount of intellectual substance and student involvement corresponding to the credit awarded. The Committee asked Assistant Dean Leslie Perelman of the Office of the Dean for Undergraduate Education to conduct a study, still ongoing, of the average time spent per week for selected subjects. The COC may decide to recommend changes in credit for such courses, should the anecdotal testimony be corroborated by the study.

In a related matter, the COC responded to a request from the Committee on Academic Performance to determine whether music performance subjects are being properly credited. The Committee also discussed the basis for grade assignments in those subjects and for coupling them to count toward fulfillment of the Institute HASS Requirement. Associate Provost Ellen Harris is helping to clarify these issues as COC consults with the music faculty to choose a uniform application of their rationale to the entire set of performance subjects. These deliberations include consideration of whether pass/fail might be an appropriate grade scheme for many or all of these subjects. The Committee was impressed with the diversity and evident excellence of the performance program.

COC deliberations regarding student petitions have entailed efforts to maximize the educational benefit to students. These situations often require consideration of proposals to broaden the definition of such categories as Science Distribution Subjects, the Laboratory Requirement, or the HASS Requirement. While the COC seeks appropriate opinions or judgements from the Schools and academic departments, it also employs a "reasonable person" criterion to balance the desire of students to repair matters at the last minute with the serious educational intent of the rule they are trying to deform. In this the Chair and the Registrar often confer "in camera," the Registrar being the institutional memory and the Chair being the constructor of trial scenarios. The Committee always arrives at a consensus.

The **Committee on Discipline** adjudicated a number of grievances against students brought to the Committee by members of the MIT community. Among these were cases of academic dishonesty, which included: multiple cases of cheating on quizzes by means of altering a returned quiz and re-submitting it for an increased grade; breaking and entering into a faculty member's office for the purpose of stealing an upcoming quiz; changing grades on a spreadsheet and otherwise removing material related to a subject; lying to faculty members and the COD in connection with a disciplinary hearing; and falsifying time cards in a UROP project. MIT received considerable attention from a single case of widespread collaboration on computer code involving some 78 students. Cases of drug distribution in living groups were also heard.

The sanctions given in these various cases included formal and informal academic probation, letters of reprimand, suspension, and expulsion.

The Committee Chair met regularly with the group of MIT staff who participate in the grievance proceedings across the Institute in order to coordinate activities and share issues and ideas. She also consulted with various members of the community about individual cases as they developed; not all of these resulted in formal COD hearings. The newly revised COD rules were placed on the Tech-Info system for ease of access by the community.

The principal activity of the **Committee on Faculty-Administration** was consideration of a set of issues related to the Report of the Committee on Sexual Harassment and the subsequent adoption of revised text in *Policies and Procedures* to reflect that Committee's recommendations. Questions were raised as to whether there had been adequate faculty discussion prior to the revisions of *Policies and Procedures*, whether the new policy on harassment might be in conflict with free speech assurances on campus, and whether the Institute's current grievance procedure should not reflect greater concern about due process.

The Committee dealt with the first two issues expecting that the third would be considered next year. The Committee recommendations were as follows:

1. Hereafter, all substantial changes proposed for *Policies and Procedures* be should be reviewed by the Faculty Policy Committee, and the FPC should raise for faculty discussion prior to adoption those proposed changes that related to faculty responsibilities or faculty terms of employment.
2. Without questioning the spirit or intent of the Institute's Policy on Harassment, the Policy should be reviewed with some help from legal counsel to assure that adequate care is taken for protection of free speech on campus.

The **Committee on the Library System** (CLS) worked on two major tasks. First, the Committee assisted the Library staff to develop plans to deal with the substantial rise in subscription costs to journals. Second, CLS helped develop plans for a major project aimed at surveying users of the library. The Committee also provided advice on the allocation of book purchase funds across the different libraries.

The **Committee on Nominations** filled approximately 40 positions available on the Faculty Committees. Nominations were also made for the positions of Associate Chair and Secretary of the Faculty. As in past years, the Committee took special care to encourage more faculty to participate in the committee process and to achieve balanced representation from departments and Schools on each of the 14 faculty committees.

The **Committee on Outside Professional Activities** (COPA) had a modicum of business this year. It was not faced with any major policy decisions. The Committee did not gather as a Committee throughout the year, which raises the issue raised by former Chair of the Committee Professor Michael Golay in his summary report of 1989. In response to the few cases raised during a year, he suggested that members of the Committee be asked to serve longer terms to form "a consensus and a set of shared values which have continuity over the years."

The Committee was not called upon to participate in the committee on conflict of interest and scientific misconduct contemplated a year ago. The Committee is concerned with both the infrequency of requests and the extent to which the Committee's work comes up against sensitive policy issues of great concern, i.e., scientific misconduct, the meaning of patents and their relationship to the Institute, and a variety of other complex concerns. These issues could have been handled by the proposed conflict of interest committee. In the absence of consideration of these larger issues and given the few cases that do come before the Committee, the chair of the Committee recommends that COPA's work be added to another Committee or that its agenda and mandate be broadened to more centrally considered policy concerns. This is advisable since there is very little legislative history for the Committee at present and there is a distinct ad hoc quality to its decisions.

Various circumstances prevented the **Committee on Student Affairs** (CSA) from meeting as frequently this year as in the preceding year. However, CSA has continued to be a forum where concerns about student affairs are aired for joint discussion by students, faculty, Office of the Dean for Student Affairs (ODSA) staff.

In contrast to the preceding year, the CSA had difficulty obtaining full undergraduate representation on the CSA, while both graduate positions were filled. The involvement and concern of the student representatives was especially gratifying. Some clarification of the process for appointing student members to faculty committees has been obtained in the process of selecting new CSA members for the coming year.

The CSA's discussions during the year mirrored the ODSA initiatives to some extent. In particular, CSA representatives participated in the ODSA's review of admission policies for transfer students and in

discussions related to the Visiting Committee on Student Affairs. The CSA regularly invited to its meeting selected MIT officials whose responsibilities directly affect student life here. In line with this, the CSA spent a substantial part of one of its meetings discussing Campus Police issues with Chief Anne Glavin.

Two of the CSA's subcommittees made some progress. The first subcommittee, chaired by Professor John Carroll, addressed issues of mutual respect and diversity. A draft report for internal CSA discussion has been produced, and a final report is expected in the fall. The second subcommittee, chaired by Professor George Verghese, concerns international student issues. This subcommittee has produced a draft questionnaire for the leaders of international student organizations at MIT. A final version is expected in the fall and will be followed up by a meeting with these leaders to discuss their ideas and concerns in more detail.

One noteworthy resolution of the CSA was that, when appropriate, meetings should be held in student living groups to encourage broader discussion and awareness of student concerns and of CSA activities. Unfortunately, the one attempt to set up a dinner meeting at a student residence fell through because of scheduling difficulties, but the Committee hopes that at least one such meeting can be arranged in the coming year.

The Committee on Undergraduate Admissions and Financial Aid (CUAFA) initiated a review of current practice relating to transfer student admissions. In the past, transfer students have not been guaranteed on-campus housing, but this policy will change beginning September, 1991. The result will be an effective cap on the combined number of freshmen and transfers admitted each fall and will necessitate new guidelines for setting the balance between transfers and regular admits.

CUAFA has been concerned about the resurgence of enrollment growth in Course VI. It is not yet clear whether the increase in the number of Course VI sophomores from 266 last year to the current 325 is a fluctuation or the beginning of a trend. As a temporary palliative, CUAFA recommended tighter control of the number of transfers indicating interest in Course VI.

CUAFA reviewed and approved a high school awards program that will be administered by the Educational Council. Awards, sponsored by alumni, titled the *MIT Alumni Award*, will be given to high school juniors "in recognition of outstanding achievement, especially in areas of mathematics and science." Each award will consist of a certificate plus a subscription to the alumni edition of *Technology Review*.

The Committee on the Writing Requirement has been actively engaged in the administration of Phase I and has continued a review of departmental administration of Phase II. The Committee also acted on 47 petitions from students.

The Committee is pleased to report that although five students were prevented from graduating on the June S.B. degree list solely because of the Writing Requirement, students are fulfilling the Requirement sooner and faculty are reporting definite improvements in the quality of undergraduate writing

The Harold E. Edgerton Award Selection Committee issued a call for nominations was distributed by direct mail to all faculty and by announcement in *Tech Talk*. Nominations were reviewed, debated, and an awardee, Professor Mehran Kardar of the Department of Physics, was selected unanimously. The Committee citation presented at the Faculty meeting cited Professor Kardar's recent research on the static and dynamic properties of surfaces, interfaces, paths, and polymers. The Committee noted that Professor Kardar's "extraordinary talents and commitment in physics research are matched by his talents and commitment as a teacher, by his good citizenship within the Institute community, and by his general friendliness, selfless helpfulness, and dignified modesty."

The **James R. Killian, Jr. Faculty Achievement Award Selection Committee** began its search for an awardee by sending out notices requesting nominations to members of the faculty and the MIT Corporation. A total of thirteen nominations were received. The Committee discussed the nominations received and came up with a short list of five for further consideration. After receiving additional information and letters of support for the nominees, the Committee selected unanimously Professor of Linguistics Noam A. Chomsky as the awardee.

In its citation, the Committee identified Professor Chomsky as “the recognized leader in the scientific study of language” and said that he has “transformed linguistics from a huge, but ineffective accumulation of imperfectly understood facts to a coherent empirical and theoretical science.” The Committee remarked on the broad impact of Professor Chomsky’s work, noting that he has “materially influenced research in certain domains of computer science as well as the study of visual perception” and recognized “the influence that Chomsky’s ideas have exercised in the field of immunology.”

The Committee had the good fortune of receiving so many outstanding nominations and that its task was made most pleasant and satisfying by having such a select group from which to choose.

Sincere appreciation is extended to the following faculty members for their special contributions and service as appointed Chairs of the Standing and Special Faculty Committees during the past year: James L. Kirtley, Jr. (Academic Performance), Kent F. Hansen (Corporate Relations), William H. Orme-Johnson (Curricula), Sheila E. Widnall (Discipline), Jack P. Ruina (Faculty-Administration), Paul Osterman (Library System), Elias P. Gyftopoulos (Nominations), Langley C. Keyes, Jr. (Outside Professional Activities), Joseph Ferreira, Jr. and George C. Verghese (Student Affairs), David J. Epstein (Undergraduate Admissions and Financial Aid), Suzanne Flynn (Writing Requirement), Ira Dyer (Edgerton Award Selection), and Uttam L. Rajbhandary (Killian Award).

HENRY D. JACOBY
SARAH T. CAMPBELL

SCHOOL OF ARCHITECTURE AND PLANNING

The past year saw positive developments in every part of the School of Architecture and Planning. These are evident in external assessments and in the internal actions begun or maturing throughout the School.

Two anniversaries were marked: In October the Media Lab celebrated its Fifth Birthday with a two-day symposium, banquets, receptions and meetings for over 2000 faculty, sponsors, staff, students and friends. In May the Community Fellows Program celebrated its 20th anniversary, holding an alumni reunion and conference, with some 200 former Fellows in attendance.

Rotch Library

Far and away the most conspicuous and welcome development in the School this year was the completion of the renovations and extension to the Rotch Library. The distinguished design of the building and renovation has attracted nationwide attention. Contributing to this successful project were the persistence and thoughtfulness of members of the MIT Library system and the exemplary support of the Institute senior administration, especially of Paul Gray, John Deutch and Bill Dickson. Throughout the construction process the resourceful Rotch staff kept the library open for its users. The result of everyone's efforts is an austere and elegant building that once again brings together the library's resources in an accessible and engaging way.

Academic Programs

In the fall the School's Visiting Committee and in the spring the Committee on Accreditation of the Association of Collegiate Schools of Planning provided external assessments of the School. The Visiting Committee gave high marks to the evident energy and creativeness in every part of the School. The report of the Accreditation Committee spoke eloquently of the accomplishments of the Department of Urban Studies and Planning and of its premiere position among planning departments worldwide.

Actions in each unit of the School advanced research and education agendas. In this fourth and last year of Bill Porter's leadership of the Department of Architecture, a creative governance process now firmly in place supported a wide-ranging recruitment of new faculty members. The results bring the Department's tenured faculty lines into their full strength and help address the demographic imbalance in the department's ranks today. Professor Stanford Anderson assumes the responsibilities of department head on July 1, 1991.

The long range planning process of the Department of Urban Studies and Planning is at the half-way point. In meetings and in a series of colloquia department members vigorously debated ideas for the identity of research clusters and for expanded development of the undergraduate program. Also addressed were the need for increased faculty responsibility and stronger internal communication.

In the face of the downturn of the real estate industry, the Center for Real Estate Development continued to build its international relationships. The curriculum reflected an increase in emphasis on portfolio management and investment, managing workouts, and global capital markets, with a corresponding decrease in focus on new development. Thomas A. Steele, former President and CEO of Perini Land and Development Company and Perini Investment Properties, assumed the position of Chairman of CRED on June 1.

The Media Arts and Sciences section's ongoing search for new faculty yielded two appointments this year. The section's planning focused on the upcoming review of its academic programs in the Fall of 1992, which will undertake an overall view of the program's achievements and of where its academic planning should be headed for the longer range future. The Media Lab's research volume was \$7.4 million.

Facilities

Despite the intrinsic problems with the physical division of a department, the consolidation of the architecture design studios in N51 and N52 to alleviate immediate space pressures brought a demonstrated energy and quality to the design work taking place in the Department of Architecture. Also in N51 Visual Arts occupied renovated studios and the newly completed Berenice Abbott

Photography Laboratory. The Media Lab, to keep pace with its development, redesigned and renovated some 2200 square feet in the Wiesner Building.

The MIT Planning Office undertook a study of the School's space and concluded that the division of the Department of Architecture into two locations is not workable on a permanent basis for the department or the School. We should begin to plan for the eventual consolidation of the Department alongside the Department of Urban Studies and Planning and the library at the core of MIT. These objectives will require thoughtful planning and cooperation right across MIT. A successful outcome will bring our teaching and research clusters into improved and productive spatial realignment.

Financial Support

The problems of student financial support are getting worse. Both internal and external reports call attention to the pressure on students created by rising tuition and declining financial aid. Evidence of the consequences include, for example: The Department of Architecture is experiencing below standard PhD admissions for History, Theory and Criticism; rejections by applicants are regularly based on our lack of competitive funding. In the fall of 1990, 23 percent of entering MCP students were minorities; in the coming year, the percentage is reduced to 13 percent. In the short term DUSP will increase available research assistantships and internships. In the longer term, the department is convinced that structural changes in the design and financing of its programs will be required.

Community Composition

The School's total enrollment increased from 578 to 615 students. Of this total 39 percent were women and 13 percent were underrepresented minorities (49 percent and 23.5 percent, respectively, in the Department of Urban Studies and Planning). The numbers of women and minority faculty members were at the same level as last year.

A special School program for underrepresented minorities will bring two visiting scholars to the School in the coming year. The Media Arts and Sciences section created a new academic staff internship position intended specifically for underrepresented minorities. The profession education program of CRED included the third session of the Minority Developers Executive Program in which our faculty teach on a pro bono basis.

Dean's Office

This year marks my tenth year as Dean of the School of Architecture and Planning. I have decided to begin a new period in my work as an architect and planner. So I have arranged to step down as Dean on January 15, 1992. After a period of leave I plan to return to MIT as professor in the departments of Architecture and Urban Studies and Planning.

The School of Architecture and Planning is a remarkable part of MIT. It has a distinctive and important role to play in the Institute's overall education and research mission and I look forward to my future participation in that role.

John de Monchaux
Dean

FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1990-1991

	1989-1990				1990-1991			
	<u>Total</u>	<u>Full Time Equivalent</u>	<u>Women</u>	<u>Minority</u>	<u>Total</u>	<u>Full Time Equivalent</u>	<u>Women</u>	<u>Minority</u>
<u>Department of Architecture</u>								
Faculty	25	24	3	0	26	26	4	0
Other Academic Staff	34	18.25	3	0	32	20	6	1
Research Staff	2	1.5	0	0	2	1.5	0	0
Without Pay	1	1	0	0	2	2	0	0
<u>Department of Urban Studies and Planning</u>								
Faculty	24	24	5	4	24	23	4	4
Other Academic Staff	17	10.5	8	3	16	11.4	8	3
Research Staff	2	1.75	-	-	2	1.75	-	-
Without Pay	18	7	8	9	11	7	7	3
<u>Media Arts and Sciences Section</u>								
Faculty	13	13	3	0	12	12	3	0
Other Academic Staff	5	4.2	1	0	4	3.2	1	1
Research Staff	1	1	0	0	0	0	0	0
Without Pay	3	2.08	0	0	1	.2	0	0
<u>Media Laboratory</u>								
Research Staff	27	24.9	2	1	33	31.87	7	1
Without Pay	17	17	2	0	15	15	0	0
<u>School Totals</u>								
Faculty	62	61	11	4	62	61	11	4
Other Academic Staff	56	32.95	12	3	52	52	15	5
Research Staff	5	29.15	0	0	37	35.12	7	1
Without Pay	39	27.08	10	9	29	24.2	7	3

STUDENT ENROLLMENT AND COMPOSITION 1990-1991

	Total	Women	Minority	International
<u>Department of Architecture</u>				
Undergraduate	110	57	11	7
M.Arch.	94	39	5	11
S.M.Arch.S.	34	12	3	21
S.M.Vis.S.	9	1	1	0
Ph.D. (resident)	16	6	1	7
S.M. Real Estate Devel.	37	6	5	5
S.M. Building Technology	6	1	1	0
Total Graduate Resident	159	61	11	42
Ph.D. (nonresident)	17	-	-	-
Special Students (nondegree)	1	1	-	-
ARCHITECTURE TOTAL	287	119	22	49
<u>Department of Urban Studies and Planning</u>				
Undergraduate	7	5	1	0
M.C.P.	95	48	30	23
S.M.Real Estate Devel.	17	5	2	1
Joint M.C.P./M.Arch.	5	4	0	3
Ph.D. (resident)	28	12	1	11
Total Graduate Resident	145	69	33	38
Ph.D. (nonresident)	27	13	2	9
Special Students (nondegree)	-	-	-	-
SPURS	10	4	0	10
CFP	12	7	12	0
DUSPTOTAL	201	98	48	57
<u>Media Arts and Sciences Section</u>				
S.M. (unspecified)	39	8	3	7
Ph.D.	37	6	3	4
Special Students	7	2	-	2
MAS TOTALS	83	16	6	13
<u>School Totals</u>				
Undergraduates	117	62	12	7
Graduate	468	165	57	107
Special Students	30	12	12	12
TOTAL ENROLLMENT	615	239	81	126

Department of Architecture

As I step down after four years as Head, I can report substantial development and change in the Department. 15 of 28 members of the faculty have been appointed during this period, and the subdisciplinary organization of the Department has been consolidated. That organization draws upon four major traditions of thought in and surrounding architecture: visual arts; history, theory and criticism; building technology; and design itself. Each subdiscipline group is competitive on a national and/or international scale, and in this respect I believe that we are unique among American schools of architecture. As one example, our History, Theory and Criticism, (HTC) PhD graduates are sought for academic positions in the best American university programs and abroad.

Further, within the four years all masters programs have been broadened and strengthened by the addition of new faculty and/or curriculum reforms. A new undergraduate curriculum, put into full effect this year, places architecture in a broader and more humanistic frame than the preprofessional model previously in place permitting specialization in the variety of areas of faculty strength. Further, visual arts education for undergraduates across the Institute has been revitalized within this department..

The stage is now set for the Department to move into a new phase, with renewed energy, and with more contemporary ways of seeing and interpreting how design can best serve society. The teaching of design in this department incorporates a view that is distinctive and sturdy, compared to many other departments in the world. It sees architecture as place- and culture-specific, as taking its cues from nature and from the nature of building materials rather than from abstractions or fashion. It is grounded in the tectonics of building, in craft, not applied styles. It derives more from vernacular sources of form than from individual monuments, emphasizing design as part of a larger fabric of building rather than as singular figures against an extensive and anonymous ground. And, rather than being polemical and didactic, it aims to be integral to democratic and pluralistic societies in its multiplicity of possible uses and interpretations.

However, this view tended in recent years toward too narrow an interpretation by some and has excluded competing ideas that are nevertheless aimed toward the same general values. But now there is within the faculty greater legitimation of a diversity of ways that these values can be achieved through design and how they can be expanded. There is also growing understanding among practitioners and educators of the distinctiveness of the Department's view and of the potential that it can achieve located within MIT.

The Department has also worked, in the last four years, to emphasize and enhance linkages to the rest of MIT. Architecture is one of the more popular majors among MIT's academic departments, with over 100 undergraduates enrolled. Within the new curriculum, an undergraduate can major in any of the four subdisciplines. This structure reflects the broad scientific and humanistic education that is the aim of the MIT undergraduate program.

Through joint teaching and research and a strong commitment to addressing important global problems and opportunities and through the incorporation of new technologies into architecture, this department hopes to continue to strengthen its linkages with others at MIT. Illustrative examples of the recent past include: work on new building materials for improved and lower cost housing; study of the residential reconstruction of Beirut; computer assisted approaches to legislative and administrative control of building that take advantage of recent developments in artificial intelligence; and computer assisted visualization of the environment built on previous work by Project Athena.

As Professor Stanford Anderson enters the job, there are immediate challenges to the new Head of the Department. First is the integration of the design faculty and reinterpretation of its academic and professional mission. The Design faculty is now comprised of two groups, the

Architectural Design studio faculty and the Architectural Studies faculty, who have in recent years functioned quite independently of one another. It was only this year that the decision to merge the two groups was made by the executive committee of the Department.

Second, within the broadened Design faculty there is still the serious need for strengthened leadership in the area of design studio teaching. In the next few years there should be opportunities for new senior and junior appointments to guarantee the possibilities for further development of this group, so central to the life and meaning of the department.

The natural development of the four subdisciplines in the Department suggests that they each have strong graduate programs capitalizing on the strengths of their faculty and the distinctive perspective created by their being in the Architecture Department at MIT. As the graduate programs in building technology and in art develop over the next few years, it will be a challenge to strike the appropriate balance between specialization and relevance to the field of architecture and to the rest of the department.

A third challenge is to make the new department work, first by articulating the extraordinary potential for architectural education that this department now has, and, second by creating opportunities for faculty and students in all the subdisciplines to take advantage of one another in their quest for improved understanding of architecture, art and building technology.

The fourth challenge is to create a more satisfactory spatial framework for teaching and research in this department, one that takes advantage of the newly articulated subdisciplines by allowing them to become stronger without becoming isolated from one another. The recent changes and developments in the Department have taken place while it has continually undergone shifts of its groups from place to place, some having to endure conditions that were unsatisfactory for teaching, learning and research.

PROGRAMS

A total of 383 students, including Media Arts and Sciences and special students, PhD non-residents, and SM in Real Estate Development degree candidates, were enrolled in Course IV this academic year. The total enrollment of Department students in residence was: 110 undergraduate BSAD candidates; 94 graduate Master of Architecture (MArch) students, 34 SM Architecture Studies (SMArchS); 6 MS in Building Technology; 9 SM Visual Studies, and 16 PhD students.

BSAD

The Department experienced a bulge in undergraduate enrollment in 1989-90 and 1990-91, and the number of graduating seniors in these two years, 54 and 42 respectively, was significantly greater than in any year since 1977-78. We expect that undergraduate enrollments will level off at about 100 and rise again slightly when our new Building Technology and Visual Arts concentrations attract more undergraduates.

MArch and SMArchS

Admissions criteria for the first professional degree, Master of Architecture (MArch), program was broadened effective this year to increase the number of advanced students in MArch design studios. Applicants with a first professional degree from another United States or foreign architecture school who were primarily interested in taking architectural design studios were allowed to apply for the MArch program. Applicants with the same qualifications who were primarily interested in research and inquiry in architecture applied, as before, for our Master of Science in Architecture Studies (SMArchS) degree program.

This change in policy produced the expected rise in MArch applicants and corresponding drop in SMArchS applications: MArch applicants from 238 to 272, SMArchS applicants from 114 to 92.

Admission of MArch students with no previous design education was increased as well (to 46), of whom a record number (25) will attend. Admission to SMArchS has been somewhat increased to 25, after a drastic cut in 1988. This was done to respond to restored faculty numbers in the program and to establish a small new group in Theory and Methods.

The increases in enrollment in the MArch and SMArchS programs bring them to full complement next year, but will pose a problem for us in providing adequate student support.

DISCIPLINE GROUPS

Architectural Studies

This group, the center of advanced design studies in the Department, was the focus of major attention by the executive committee and involved a search for three faculty members. Professor Julian Beinart chaired the search committee whose members came from the Architectural Studies, Design, Building Technology and HTC faculty. From a field of 200 candidates, three excellent people whose areas of experience and skill both strengthen and complement the existing faculty were chosen: Michael Dennis, as Professor of Architecture with tenure; Roy Strickland, Associate Professor without tenure; and Sibel Bozdogan, Assistant Professor of Architecture. With these appointments plus existing resources, the group is in a position to build an extremely fine advanced studies program and to assist in setting the Department on a vigorous path of regeneration.

Architectural Design

In its second year as a self-governing group, the Architectural Design faculty found itself together in renovated office, exhibit and studio spaces in Building N51-52. The spatial arrangement fostered a marked increase in openness and collective action, which has aided the group in addressing issues of curriculum, new programs and research.

The decision to join the Design studio and Architectural Studies faculties has begun an exchange between the two groups which will only increase in the coming year. Discussions are projected to treat revision of program curricula and architectural research related to the contemporary profession.

Three key appointments were made in Architectural Design in 1990-91. First, Shun Kanda, was promoted to Senior Lecturer and included among the senior design teachers; Renee Chow and Wellington Reiter, first hired as Lecturers from a search in 1989, were appointed Assistant Professors, effective July 1, 1991. The appointment decisions were made following a policy to convert part-time and academic staff back to previously vacated full time faculty positions. And these new appointments add younger members to the permanent faculty teaching design.

Building Technology

This year saw 10 BSADs in the building technology concentration. The MS in Building Technology is getting up to speed with a total of 8 students enrolled in the second year of that program. The PhD group will increase in number as research opportunities grow and as a larger cadre of qualified MS students emerges. The Department will propose that the Institute approve a BS in Building Technology (BT) degree, to be more technological in focus than the BSAD. The BS in BT would be an accredited engineering degree, presumably based in Course IV but cooperative with the departments of Mechanical and Civil Engineering.

Emphasis in this group too is on permanent faculty, rather than an array of part time specialists. An assistant professor specialized in structural engineering, hired from a search last year, brought the complement of faculty to six. A search to fill an additional faculty slot, in HVAC and Building Controls, has been ongoing this year. As with all faculty in the discipline group,

emphasis on the faculty members' expertise in building technology and his/her ability to relate to teaching in architectural design, as well as to cross over to relevant engineering departments.

Work in Building Technology is in the traditional MIT style of research-based education as in the Civil and Mechanical Engineering departments. Though development of research demands a large share of faculty time, BT has \$60,000 of active research on housing in hand and is hoping for further growth. Unfortunately, research in this area is subject to the volatile business cycle which affects housing, and there seems at present not to be long-term support. However, ventilation and "smart building" are areas of inquiry that are reviving as is research into energy conservation. Present sponsors are, among others, the Department of Energy, the Environmental Protection Agency, National Institute of Standards and Technology, Dow, Weyerhaeuser, Shimizu. The department hopes to see interdisciplinary, even interdepartmental research work generated on issues of building that relate it to urgent energy and environmental concerns.

History, Theory and Criticism

Appointment in the spring term of the new Aga Khan Professor for History of Islamic Architecture brought the HTC group to its full complement of faculty.

Despite the regular appointments to all faculty positions in HTC, the next years will see a diversity of visiting faculty owing to a number of causes. Professor Anderson has been named Department Head. In his place two distinguished visitors are projected to teach with us one term per year for at least the next four years: Royston Landau, Head of the Graduate Program of the Architectural Association in London, and Akos Moravansky, a noted Hungarian architect and scholar most recently at the Getty Center in Santa Monica. Professor David Friedman will assume the directorship of the History, Theory and Criticism group vacated by Professor Anderson. Professor Leila Kinney is on a leave of absence to conduct her own research and will be replaced in 1991-92 by Ewa Lajer-Burcharth. Professor Benjamin Buchloh is undertaking an appointment with the Whitney Museum in New York and will be granted a half-time leave for the next three years. Francesco Passanti is on leave to pursue his own research this fall. In his line we shall have a bright young scholar from Belgium, Hilde Heynen. These numerous changes will bring a rich diversity of subject offerings to the program, but this will also be a challenge to the coherence of the program and the direction of doctoral students.

The HTC section continues to provide substantial services to Institute undergraduates in Humanities Distributions subjects and/or satisfaction of the undergraduate writing requirement. These services consume substantial department resources and need to be factored into department planning. Current faculty, especially in the history of art, are stretched to the limit in undergraduate teaching, as are graduate students who assist them. Further, our increased enrollments, especially in art history subjects, continue to strain the dilapidated spaces available to us for lecture and seminar teaching. No progress on upgrading this space has been made, despite repeated requests by the department.

Unlike 1990, the 1991 admissions experience in HTC was below our standards in numbers, possibly in quality. Rejections by applicants are regularly based on our lack of competitive funding. Ironically, recent graduates of the doctoral program continue to receive much attention in the job market and have taken up positions at noted departments.

Visual Arts

Undergraduate enrollments in visual arts subjects continue to be high. The program offered two sections of the foundations subject, each team-taught by two faculty members, and both enrolled to capacity. Advanced sculpture and photography subjects were filled by students from across the Institute. Visual Arts took occupancy of its newly renovated space in building N51, with large studios and a shop available on the first floor and the third. In October 1991, the Berenice Abbott Photography Lab was completed and dedicated. The facility provides equipment and

support for traditional photography techniques in close proximity to computer and video equipment for mixed media production.

Visitors included environmental artist Dennis Adams, who came to speak in the Department Lecture Series; Krzysztof Wodiczko, who also spoke in that series and spent three weeks in residence in the program; Mierle Ukeles, who gave a lecture and met with individual classes and students; and Professor Takura Osaka, who gave a multi-media presentation of his own work and spent two weeks in the program working with students. Professor Osaka was the first visiting artist to come to MIT from Japan's Musashino Art University under the newly established MIT/Musashino Exchange Program.

FACULTY

Three new people were appointed this year to the tenure-track faculty. Leonard Morse-Fortier, Assistant Professor of Building Technology, is a civil engineer, specialized in structural engineering. He came to MIT from Notre Dame, where he had held a teaching post since 1986. Ritsuko Taho began an appointment as Assistant Professor of Visual Arts. In May 1991, Professor Taho, a sculptor of growing national renown, was named to the Cecil and Ida Green Career Development chair for a two year term--the first career-development teaching chair in the visual arts at MIT. Finally, Nasser Rabbat was named Aga Khan Assistant Professor in the History of Islamic Architecture. He joined the HTC group in January, 1991, the first choice from an international search to fill the post. Professor Rabbat is trained both as an historian and an architect, holding a BA and MArch in Architecture and a PhD from this department's HTC group.

Professor Sandra Howell was promoted to Professor; Mr. Kanda was promoted to Senior Lecturer. Professor Ronald Lewcock took a sabbatical leave in the fall term and was replaced by Ahmet Gulgonen, architect and teacher from the Ecole d'Architecture, Paris Belleville for the first half of the term and Nabil Tabbara, chairman of the Department of Architecture at the American University of Beirut for the second. At the end of this academic year, Professor Lewcock will resign his position in the department to join the Georgia Institute of Technology's Department of Architecture and to return to his research work at Clare Hall, Cambridge University. He will also continue with MIT as Visiting Aga Khan Professor.

Distinguished visitors in Architectural Design were Gunter Bock, former head of the Department of Architecture at the Stadelschele Art Academy in Frankfurt; Luise King, architect and professor at the Technische Universitat in Berlin; and Otto Steidle, distinguished practitioner and teacher from Frankfurt. The three visitors taught an advanced architectural design studio in sequence, each assigning projects sited in the newly unified city of Berlin. Professor Reiko Tomita, who taught here in fall 1987 with other members of her firm, Team Zoo, collaborated with Shun Kanda for a part of the term teaching Level II studio. Cameron Roberts joined the department as a Lecturer and taught Level I and II architectural design studios in the spring and fall.

Lecturers in Architectural Studies: Peter Droege taught in the Environmental Design group; Julie Moir Messervy, (MArch, MCP '78) led landscape design subjects (a submission from her studio to the Boston Holocaust Memorial competition received an honorable mention in April); Hashim Sarkis, formerly a fellow at the Chicago Institute for Architecture and Urbanism (the SOM Foundation), taught and played a key role in a research project on the residential reconstruction of Beirut

Visitors in HTC were David Stewart, from Tokyo Institute of Technology and the University of Tokyo, Jamel Akbar, from King Faisal University, Saudi Arabia; and Therese Lichtenstein, the New School, New York.

OTHER

Special Interest Group in Urban Settlements (SIGUS) activity this year focussed on housing problems now facing Poland's new government. A two-week program on site in Kazimierz,

Poland, was offered jointly with the Oxford Program of International Studies in Design and Development. Professor John Myer, Principal Research Associate Reinhard Goethert, and 16 students from MIT were joined 13 students from the Oxford Polytechnic, led by Nabeel Hamdi, former Lecturer in this department, and 11 students from Poland.

Lecturers in the Department series included: Eric Owen Moss, Krzysztof Wodiczko, Henry Smith-Miller and Laurie Hawkinson, and Hans Haacke, among others; the Environmental Design Forum featured talks by faculty on current projects. Mr Sarkis coordinated an exhibition of urban design projects for the reconstruction of Beirut titled "Demarcating Lines". The exhibit was offered in collaboration with the American University of Beirut.

Student Awards and Prizes: Paul Chinhaho Wang received the William E. Chamberlain Prize as the outstanding undergraduate; Varisara Gerjarusak received the Sidney B. Karofsky Prize as the outstanding student entering the final year of study in the professional program; Susan Christine Dunbar, Emily Rai-Pi Huang, and Roy C. Robinson, Jr. were given the Francis Ward Chandler Prize for achievement in architectural design; the Alpha Rho Chi Medal went to Michael Joyce, for promise of real professional merit; Christopher Falliers and Kairos Shen shared the AIA Medal as top-ranking students graduating from the MArch program this year; and James Thomas Rojas was chosen for the Department award as the top student awarded the SMArchS degree this year.

WILLIAM L. PORTER

Department of Urban Studies and Planning

INTRODUCTION

For DUSP, 1990 - 91 was a year of assessment, reflection, and planning. In the Fall, we were reviewed by our Visiting Committee; in the Spring, by the Committee on Accreditation of the Association of Collegiate Schools of Planning. The reports of both committees were highly favorable to us. They praised our strengths and noted our continuing leadership in the fields of planning and urban studies. Coincidentally, in this same year, a study of the comparative influence of 32 urban studies programs throughout the country, based on citation indices, placed DUSP well ahead of any other program.

At the same time, the two examining committees called our attention to problems with which we should be concerned: the pressure on students created by rising tuitions and declining financial aid, the urgent need to bring more sponsored research into the Department, and the importance of enhancing the quality of communication and community among faculty members and between faculty and students. These issues are of concern to us. They were among the issues that led us, a year ago, to begin a two-year Long Range Planning Process.

THE DEPARTMENT'S LONG-RANGE PLANNING PROCESS

In this process, we aim at re-assessing our directions and strategies, guiding the future development of our educational and research programs, and informing the personnel actions we will take over the next decade. A 12-member committee of the senior faculty, chaired by myself and Professor Phillip Clay, with staff support by Amy Schectman, has reviewed our mission and overarching values, analyzed ongoing and likely future changes in our principal environments (the urban world, the professions related to planning and their schools, MIT), and has begun to draw from these studies implications for our policies and programs.

These are some of the highlights of our work to date:

1. We seek to become a department of planning and development, meaning land development and its consequences for the environment, affordable housing and community development, and development in the Third World. The scope of our inquiry into development will include policy analysis, planning, design, implementation, and public management. This shift is a deliberate move on our part to combine faculty scholarly research with the application of knowledge in 4-5 domains. The areas of our special interest, outlined below, are areas where we are clear leaders in the field and therefore have some competitive advantage. This sharpening of focus will have immediate payoffs for the teaching program at all levels.

2. Consistent with this direction, we have organized the Department into 5 research clusters: Land Development and Design; Environmental Policy and Planning; Poverty and Development (in the Third World); Employment and Community and Regional Development; and Planning and Decision Support Systems (with an emphasis on Geographic Information Systems). The purpose of this reorganization is to provide a more coherent basis for our doctoral program and a stronger platform for generating sponsored research.

In the Spring of 1990, each research cluster held a department-wide colloquium in which it presented its proposed research agenda. We are continuing to work

out the implications of the research clusters for budgeting, salary administration, hiring and promotion. The effects on research activity have already been noticeable, with the volume of sponsored research and proposal-writing several times that of the previous year.

3. We will strengthen our undergraduate program, emphasizing public policy and planning related to the persistent problems of the cities and the environment. Our aim is to expand the number of large, regularly attended undergraduate subjects in our field; to make a modest increase in the number of majors, and a significant gain in our share of concentrators and minors. Our faculty has begun to respond to this initiative, with a step-function increase in our participation in "commons" activities such as IAP and Freshman Advisor Seminars.

4. We will build on and extend our alliances with other units in MIT, including Civil Engineering, Architecture, parts of the Sloan School, and Political Science.

The draft report of the Long Range Planning Committee is being prepared this Summer. In the Fall, we will review it with our Department, our alumni, the School of Architecture and Planning, and the MIT Administration. In the course of the next academic year, we will fine-tune and implement the strategies outlined above.

In addition, a special committee on financial aid, under the direction of Professor Phillip Clay, will address what is perhaps our major predicament: the inexorably increasing gap between tuitions and the level of financial support we are able to offer our graduate students, especially the minority students whose education has been one of our principal concerns. In the short term, by increasing the number of research assistantships and internships available to our students, and through the use of dedicated resources provided by the MIT Administration, we believe we will be able to maintain a steady course, though with some reduction in the proportion of minority students in our master's program (last year, 23% of our entering MCP students were minorities; in the coming year, the percentage will be reduced to 13%). In the longer term, we are convinced that structural changes in the design and financing of our programs will be required.

EDUCATIONAL PROGRAMS

What Tunney Lee said of our PhD and MCP programs in last year's report still holds true: these are among the most successful programs in the country, with high ratios of applications to admissions revealing a continuing ability on our part to attract highly qualified students in competition with our lower-cost competitors in the large state universities.

Our pioneering programs in developing countries, and in environment planning and negotiation, have continued to attract large numbers of students and have maintained their high levels of quality. Our programs in housing and environmental design have benefitted from a much closer collaboration with the Center for Real Estate Development. And a new program in Geographic Information Systems, under the direction of Associate Professor Joseph Ferreira and Assistant Professor Lyna Wiggins, has achieved a major presence in the Department in the past year, both in its research base and in the number of students engaged in coursework and thesis research.

One indication of the quality of our PhD and MCP programs is the number of students who have received prestigious awards and fellowships. For example, two

of our first-year MCP students -- Gabrielle Watson and Hnin Hnin Pyne -- received Carroll Wilson Awards for Summer master's thesis research. Among our doctoral students fellowships were won by (among others): Lynn McCormick, Economic Policy Institute; Peggy Levitt, MacArthur Fellowship from the Harvard Center for Population Studies; Meenu Tewari, MacArthur Fellowship, for doctoral research in the Punjab, India; Jonathan Raab, a Japan Endowment Fund Fellowship from MIT's Center for International Studies; Eric Dolin, Switzer Fellowship; Elizabeth Shaw, Ida Green Fellowship.

In the coming year, we will continue our efforts to improve our PhD and MCP Programs in the light of the directions set out in our Long Range Planning Report. The PhD Committee will continue the work of adapting our doctoral program to the research agenda of our 5 research clusters. A task force on the MCP Degree will focus on further articulating the practice competencies for which we want to educate our students, building our curricula in housing and community economic development, and reconciling our emphasis on core subjects and thesis-writing with the expansion of subject offerings in specialized fields.

The Community Fellows Program under the direction of Adjunct Professor Melvin King had a very successful year, hosting 12 mid-career professionals whose work has focussed on youth programs in cities around the country. In the coming year, with support of \$146,000 from the Ford and the Rebok Foundations, we expect 12 new Community Fellows.

The Special Program for Urban Regional Studies (SPURS), under the direction of Dr. Gillian Hart, was able to maintain a high quality program, in spite of the loss of the Humphrey Fellowships. Fourteen SPURS Fellows, from 13 different countries, participated in the program. In the coming year, Professor Karen Polenske will replace Dr. Hart as SPURS director.

EVENTS

In the Spring, the Department sponsored 6 colloquia, each of which drew an audience of 40 to 50 faculty and students. Five of these were devoted to the newly formed research clusters, described above. The 6th dealt with intellectual questions underlying issues of race, ethnicity and gender.

The Department's Professional Development Institute, under the direction of Amy Schectman, was held for the third time in January, jointly with the Tufts Planning Program. Eighteen workshops in skills of communications, writing, management, and GIS Systems, among others, were offered to approximately 180 DUSP Alumni and master's students from DUSP and Tufts.

SPURS presented weekly, well-attended lunch-seminars, with a series of distinguished speakers that included Professor Paul Samuelson, of MIT; Professor Ira Katznelson, of the New School for Social Research; Professor Richard Locke, of MIT's Sloan School; and Professor Annalee Saxenian, of the University of California, Berkeley.

In connection with the search for a new faculty member in planning and real estate development, the Center for Real Estate Development and DUSP jointly sponsored three colloquia on topics in real estate economics, given by Kenneth Rosen, Peter Chinloy, and Dennis Capozzo. (Professor Capozzo will be a Visiting Professor at CRED and DUSP in Fall of 1991.)

The Community Fellows Program, celebrating its 20th anniversary, held an alumni reunion/conference in May, with about 200 former Fellows in attendance.

FACULTY

One of the issues of central concern to us is the mix of faculty in DUSP. We seek to increase the number of minorities and women on the faculty, to strengthen our junior faculty in the light of the increasing ratio of tenured to total faculty, and to achieve a balance of faculty members who devote themselves, respectively, mainly to scholarship or mainly to practice-oriented research. These concerns are heightened by changes that have occurred in the past year: Professor Bennett Harrison announced that he would not return to MIT from his extended leave at Carnegie Mellon University; Professor Frank Jones announced his plan to take early retirement as of February, 1992; and Dr. Gillian Hart accepted a faculty position at the University of California, Berkeley. In addition, there was the welcome news that Associate Professors Bish Sanyal and Mark Schuster received tenure; Patricia Hynes was given a three-year appointment as Adjunct Professor, and Philip Herr's appointment as Adjunct Professor was renewed.

In our search for new faculty to take the place of Professors Harrison and Jones, we will give priority to the hiring of women and/or minorities; and we will seek to make at least one of these appointments at the junior faculty level. In the coming year, Omar Razzaz and Jesse Ribot, both junior faculty, will teach in the Developing Countries area. And Richard Schramm, who has held a Visiting Faculty appointment, will continue as Lecturer with special responsibilities in the field of community economic development.

Visiting Scholars were: Yale Rabin, from the University of Virginia; Turid Horgen, an architect/planner from Norway; Reginald Griffith, Executive Director of the National Capital Planning Commission; Richard Klosterman, from the University of Akron; Grazia Gioe, from the University of Reggio Calabria in Italy; Maria Fuente, from the University of Complutense in Madrid, Spain; and Alan Black, from the University of Kansas.

On sabbatical or other leave in 1990 - 91 were Professors Bernard Frieden, Tunney Lee, and Gary Marx.

Some of the highlights of faculty activity in the past year were as follows:

Professor Phillip Clay received a research grant of \$850,000 from Ford and other foundations, to evaluate "YouthBuild" development programs.

Adjunct Professor Patricia Hynes published Reconstructing Babylon: Women and Technology, of which she was editor, in Spring, 1991; her EarthRight for Children is scheduled for publication in 1992.

Professor Gary Marx received the Distinguished Scholar Award from the American Sociological Association for his book, Undercover.

Assistant Professor Edwin Melendez continued his research on Latinos and poverty; Hispanics in the United States Labor Force, of which he is editor, will be published by Plenum Press in 1991.

Professor Karen Polenske received a \$200,000 research contract to evaluate procedures currently used by the South Coast Air Quality Management District of

California to assess the socio-economic impacts of proposed air quality regulations. She also presented a paper, "Distributional Consequences of Transformations in Property Rights," at a seminar on Regional Diagnostics and Regional Management, Leningrad Institute of Economics and Management.

Professor Martin Rein's book, Time for Retirement, will be published by Cambridge University Press in September, 1991; his Age, Work and Social Security is scheduled for publication by MacMillan Press in 1992.

Professor Donald Schon delivered invited keynote talks to the International Design Research Conference at Delft, The Netherlands, and the International Artificial Intelligence in Design Conference at Edinburgh, Scotland, in June, 1991.

Associate Professor Mark Schuster directed the Northeast Mayors' Institute on City Design, Sponsored by the National Endowment for the Arts, in Spring, 1991. In Fall, 1990, he was Fulbright Scholar and Distinguished Visitor, sponsored by the Queen Elizabeth II Arts Council in New Zealand.

Assistant Professor Paul Smoke's book, The Fiscal Role of Local Government in Developing Countries: Lessons from Kenya, will be published by Oxford University Press in 1992.

Professor Lawrence Susskind continued his extensive writing, teaching and research in public sector and environmental dispute resolution, and continued as Head of the MIT-Harvard Public Disputes Program.

Professor Judith Tandler's report, New Lessons from Old Projects: The Dynamics of Rural Development in Northeast Brazil, was published by the World Bank and translated into Portuguese by the World Bank for circulation in Brazil. She also travelled to Ecuador as consultant to the president of the Rockefeller Foundation on a proposed grant to a development foundation in that country.

Assistant Professor Lawrence Vale's book, Architecture, Power and National Identity, is scheduled for publication by Yale University Press in December, 1991.

Assistant Professor Lyna Wiggins gave invited presentations on Geographic Information Systems at the Massachusetts Geographic Information Committee, the Environmental Systems Research Institute at Redlands, California, and the Department of City and Regional Planning at the University of California, Berkeley. Together with Professor Joseph Ferreira, she received awards for research in Geographic Information Systems from the National Capital Planning Commission, The Region One Transportation Center, and other sources.

DONALD SCHON

Aga Khan Program for Islamic Architecture

The Aga Khan Program for Islamic Architecture (AKP), established in 1979, functions jointly at MIT and Harvard University to promote research and teaching concerning architecture and urbanism in countries with Islamic societies. Generous gifts from His Highness the Aga Khan support the AKP through endowed funds that provide for faculty, student financial aid, library facilities, and research; additional current funding supports publications, documentation, student travel, and outreach activities. The central office, located at MIT, serves as a continuous liaison for activities carried out at both universities, coordinates joint, program-wide activities, maintains a steady exchange of fiscal and substantive information between the program and the donor, and coordinates program outreach in the Third World.

During the 1990-91 academic year, the central office continued its communications and outreach work for the program. Internal communication between and among students, faculty, staff, and the Harvard and MIT communities functioned through the AKP monthly internal calendar and announcement listings that together alerted the community of program activities and resources, staff travel, program meetings, and special events. For students exclusively, the central office compiled and distributed listings of potential jobs as well as grant and scholarship opportunities. Two issues of the third volume of a program-wide newsletter, which reports on the program's many activities was produced and distributed to interested scholars, professionals, and institutions at home and abroad. A new publications brochure was compiled and distributed. The "Evening With" series, six lectures and discussions led by noted scholars concerning the study of the Islamic heritage, was continued. As part of the AKP's Parallel Centers program of international outreach, an international search for a Visiting Aga Khan Professor for the University of Jordan in Amman was completed. At Dawood College, Karachi, Pakistan, graduate studies enrichment and development is underway.

Three new publications were released. *Muqarnas 7* is the seventh edition of the program-sponsored annual that represents new work in the field of Islamic art and architecture; *Al-Mustalahat al-Mi'mariyya fi al-Watha'iq al-Mamlukiyya* (Architectural Terms in Mamluk Documents) by Laila A. Ibrahim and M.M. Amin is a glossary combining lexicographic and architectural explanations of Mamluk terms; *Urban Regeneration and the Shaping of Growth--Restructuration et Croissance Urbaine* are proceedings from a seminar held in Paris in 1988 by the Aga Khan Unit for Housing and Urbanization and co-sponsored by the Institut du Monde Arabe.

FACULTY

As a result of a review of the program in 1989-90, a new Aga Khan Program Committee was established to replace the Executive Council in September 1990. The committee has been charged with policy decisions during the 1991-94 cycle. Members include: John de Monchaux, dean, School of Architecture and Planning, MIT (chair); Barbro Ek, director, Aga Khan Program (ex officio); Oleg Grabar, Institute for Advanced Study, Princeton; Philip S Khoury, acting dean, School of Humanities and Social Sciences, MIT; Ronald B Lewcock, Aga Khan Professor of Architecture and Design for Islamic Cultures, MIT; Brendan A Maher, dean, Graduate School of Arts and Sciences, Harvard; Gerald M McCue, dean, Graduate School of Design, Harvard; Roy Mottahedeh, chair, Islamic Studies Committee, Harvard; William L Porter, head, Department of Architecture, MIT; John Shearman, chair, Department of Fine Arts, Harvard.

Other MIT faculty during 1990-91 included Messrs. Akhtar Badshah, lecturer/research associate in the Design for Islamic Societies unit (DIS), Masood Khan, lecturer in the DIS unit, and the newly appointed Aga Khan Assistant Professor in the History, Theory and Criticism Program, Nasser Rabbat. In addition, Jamel Akbar, a 1984 alumnus who is now a professor of architecture and urban planning at King Faisal University, was a lecturer in the History, Theory and Criticism Program in the fall; Ahmet Gülgönen, professor of architecture at l'Ecole d'architecture, Paris-Belleville, taught the first half of the fall DIS studio workshop which focused on Bursa, Turkey; and Nabil Tabbara, chairman of the Department of Architecture at the American University in Beirut, led the second half of the DIS studio workshop which dealt with the reconstruction of Beirut.

ACADEMIC PROGRAMS AT MIT

The Design for Islamic Societies (DIS) component of the SMArchS program

This year, six new students were enrolled in the DIS component of the Master of Science in Architecture Studies (SMArchS) degree program. With six outgoing students, the unit accommodated 12 SMArchS students and one PhD student. The faculty consisted of Professor Lewcock, Mr. Khan, Mr. Badshah, visiting scholars and architects, and other affiliated faculty at MIT and Harvard, who participated as visiting critics. Professor Lewcock was on sabbatical for the fall semester. In his place, Visiting Professors Ahmet Gülgönen and Nabil Tabbara taught at the unit, each for seven weeks. In the spring semester Professor Lewcock returned to direct the design workshop.

Student reflection and debate focused on both practical and theoretical issues concerning the architecture characteristic of nonwestern societies. Students were encouraged to compare traditional, Islamic architectural forms and structures with those developed after the spread and application of Western ideas in modern times. The unit considered appropriate responses to climate, building materials, and building technology as well as the socio-cultural attitudes and values that directly relate inhabitants to their environment.

In the fall of 1990, first-year students participated in two workshops that together formed the introductory course, "Architecture and Urban Contexts in Islamic Societies," a course dealing with a number of major issues vital to architectural and urban development in Islamic societies, as well as in other cultural regions in the developing world. On this occasion, as in previous years, the workshops were essentially issue-oriented. Staff and students worked closely together throughout the series, but also independently for short periods to explore particular issues.

The first workshop familiarized students with Islamic as well as other Asian and African urban and social organization. It further considered the relationship between the urban structure of traditional societies and that of cities or parts of cities that have developed under Western influence. In 1990, the center of Bursa, Turkey, a well-preserved example of Ottoman urban complex was selected for study. Students primarily examined a characteristic building type in Ottoman Turkey, the *kulliye* (or college) which has presented problems in its relation to ordinary buildings in the city because of its strong form and its resistance to change. This relation, however, is now undergoing transformations. Students in the workshop consequently examined these changes between the residential fabric of the city and the *Kulliye* of the early Ottoman sultan, Bayezid Yildirim, and proposed new housing developments in the neighborhood around the *kulliye*.

The second workshop considered the design of public buildings in terms of monumentality, taking an old market area and the "Martyrs Square" in Beirut, Lebanon, as examples for study. Students had to contend with the destruction the city has undergone due to the war and were asked to propose in the form of sketches the reconstruction of these parts of Beirut.

In addition to the design workshops, DIS offered two other courses in the fall of 1990. "Architectural Theory and Function in Asia and Africa with a Special Reference to Islamic Societies" was taught by Mr. Khan along with Professors Tabbara and Gülgönen. The course, consisting of lectures on theory, criticism, and architectural design in developing societies of Asia and Africa, had three aspects. The first considered the development of design attitudes and methods in terms of prevalent economic and cultural conditions, climate, and appropriate building materials. The second aspect dealt with theoretical approaches to creativity in Islam and the functional characteristics of design in the architecture and urbanism of Islamic societies. Thirdly, students in the course examined contemporary practice in the developing countries of Asia and Africa, focusing on the Islamic world, in a more international context. "Introduction to Architecture of Urban Neighborhoods in Transition," devised specifically for undergraduates, was taught by Mr. Badshah. This exploratory course introduced urban neighborhoods in both the Western and nonwestern worlds, relating Boston's North End to various neighborhoods in the nonwestern world, particularly Sana'a in the Yemen Arab Republic, Lahore in Pakistan, Fez in Morocco, and Ahmedabad in India. The course highlighted the uniqueness of each place, outlined the salient features of its urban environment, its people, and the problems facing these neighborhoods. It then focused on the architecture and architectural details and their role in determining change.

The spring term was devoted to a studio workshop, "Architectural Design in Islamic Societies," that considered a specific architectural design in a rapidly changing traditional environment. The workshop confronted such issues as architectural precedence, changing urban lifestyles, and the initiation of urban rehabilitation. This spring's studio workshop was divided into two parts. The first, smaller part dealt with the redesign of the area around the famous Registan square in Samarkand, USSR, with particular emphasis on the relationship between the traditional market and the neighborhoods surrounding it. The second, larger part entitled "Studies in Architectural Appropriateness: Design with the Past and Present," required the design of a vocational training center for Mehrauli, a suburban village of Delhi, India.

The spring studio workshop also included a two-week practical building workshop devoted to traditional building materials and methods still widely used in Europe, Asia, and Africa. Practical work was accompanied by lecture courses and seminars emphasizing the development of design attitudes and methods that consider indigenous conditions, climate, appropriate building materials, and theoretical approaches to creative activity in Islam.

In addition, "Special Problems in Architecture and Social Change: The Genesis of the Built House and Society," a course normally taught in the fall semester, was offered instead in the spring this year because of Professor Lewcock's fall sabbatical. This course reconsidered architectural expression through the discussion and illustration of house forms in relation to determinants, beliefs, and use. Areas of study included differing conceptions of courtyard houses, covered courtyard types, hall-houses, symbolic forms, cosmological concepts, and built form representations of reality with examples from Asia, Africa, Europe, and America.

History, Theory and Criticism Program (HTC)

In January, 1991, the History, Theory and Criticism Program in the Department of Architecture appointed recent HTC graduate Nasser Rabbat, Aga Khan Assistant Professor in the History of Islamic Architecture. This spring, Professor Rabbat taught "The History of the Mosque" and "Issues in Medieval Islamic Urbanism." In the fall, Jamel Akbar taught two courses for the HTC Program: "Tools, Conventions and the Everyday Environment" and "The Structure of the Muslim Built Environment."

The Aga Khan Component of the History, Theory and Criticism Program admitted one new doctoral student, Imran Ahmed. Of the six AKP doctoral students in the program, Imran Ahmed, Shirine Hamadeh, and Khaled Asfour were in residence in Cambridge. Kara Hill was in Minnesota writing her dissertation. Iffet Orbay was in residence in Quebec, writing her dissertation. Richard Brotherton continued work on his dissertation while based in New York. Nasser Rabbat completed his dissertation in January, 1991.

VISITING SCHOLARS

During 1990-91 the AKP welcomed four visiting scholars to the program. Adil Mustafa Ahmad, an associate professor at the University of Khartoum, was in Cambridge between February and May to study, *Beyond the Arch: Whatever petrified Arab architecture? Mukkadima Muchtarowna Ashrafi*, the chief scientific researcher at the Institute of History, Tadjik Academy of Sciences, USSR, was in Cambridge from November to February studying twelfth- through seventeenth-century Islamic miniature painting and architecture. Tarek Fadaak, chairman of the Department of Urban and Regional Planning at the College of Engineering, King Abdul Aziz University, Jeddah, Saudi Arabia, researched low income housing policy guidelines for Saudi Arabia with the Aga Khan Unit for Housing and Urbanization at Harvard University. Shakeel Hossain, a 1988 DIS alumnus, was with us from January to June to continue work on his project, *Ta'zia: Ephemeral Architecture of the Shi'a*.

STUDENT SUPPORT

Tuition and living expenses for four doctoral and 11 SMArchS students at MIT were funded in whole or in part. Five students from MIT and one from Harvard were awarded summer travel grants for research in Syria, Pakistan, Turkey, Morocco, Algeria, Mali, Switzerland, and Germany. An additional seven MIT students, one Harvard student, and one student from the Parallel Center at Dawood College, were awarded travel funds to participate in internship programs in Yugoslavia, Pakistan, and Jordan.

LIBRARY AND INFORMATION RESOURCES

Specialized acquisitions and services at the Rotch Architecture Library continued to be provided through endowed funds. Under its Information Services and Technology unit, the videodisc prototype project has been completed, and the images system is available for public use at the Rotch Visual Collections under the supervision of Kim Lyon, curator of the AKP Visual Archives. This year, Ms. Lyon assisted a total of 42 students, scholars, and visitors in the use of the images system. Among Ms. Lyons other activities was a visit to the Aga Khan Award for Architecture headquarters in Geneva at which time she gathered 800 unique high-quality images documenting 1986 and 1989 nomination sites.

This past summer, Hasan Abu-Khadra, a librarian from the Department of Architecture at the University of Jordan, and Murlidhar Dawani, a lecturer of architecture and photographer from Dawood College, visited the Aga Khan library collections at Harvard and MIT. Each attended orientation sessions with the AKP library staff who advised them on establishing book and visual collections.

The AKP book collection at the Rotch Library has become a well-known and valuable source for many. Besides regularly serving students and faculty, Omar Khalidi, reference librarian for the AKP at the Rotch Library, assisted such diverse groups as architectural firms rebuilding Kuwait, the Department of Defense, and a professor of architecture from Beriut who found at the Rotch Library books on architecture published in Lebanon but no longer available there.

SEMINARS

This year, the AKP, in conjunction with the Aga Khan Trust for Culture and the Aga Khan Award for Architecture, planned the first in the series of "Environmental Innovation Workshops," workshops for which talented young architects are to be recruited to address contemporary urban and architectural problems in Third World cities. The aim of the series is to locate new, young talent and to provide a forum for the next generation to voice their ideas about architecture and its future. The first workshop was to be held in Dhaka, Bangladesh this past January and its theme was to be Louis Kahn's capitol complex and its relation to changes in the city of Dhaka. The workshop, however, was postponed.

RONALD B. LEWCOCK and BARBRO M. EK

Center for Advanced Visual Studies

Through projects, research and teaching the Center for Advanced Visual Studies has continued its efforts in art-science-technology emphasizing large-scale performance, art-and-architecture and ecology.

In its 24-year history CAVS has hosted almost 180 Fellows - mostly artists - and 75 graduate students have received a Master's degree in its MSVisual Studies/Environmental Art and Performance Program. CAVS has hosted and participated in many international conferences, exhibitions and artistic projects. Because CAVS is the first academic institution dedicated to art-science-technology many planners and founders of new centers and programs have sought advice at CAVS in recent years towards new developments internationally and nationally. Consequently CAVS has planned and executed a large international conference, ARTTRANSITION '90, as a forum for artists, scientists, scholars, planners and ecologists to exchange information in lectures, seminars, events and performances on the "state of the art" in art-and-technology and to project ideas and plans toward the movement's progress. ARTTRANSITION '90 followed the original 1975 CAVS/ARTTRANSITION conference in its quest for vision and resulting practice in the "arts of the future". Substantial international collaboration became a major factor toward the realization of the 4-day symposium and its media events; among its main constituent partners were: The Academy of Media Arts, Cologne; Zentrum für Kunst und Medientechnologie Karlsruhe; LEONARDO, Journal of the International Society for the Arts, Sciences and Technology; Carnegie Mellon University/Studio for Creative Inquiry; CETECH/Jack Lang, Ministère de la Culture, Paris, France.

Georgy Kepes, CAVS founding director emeritus, was the Honorary Chairman; Prof. Ellen Harris, MIT Associate Provost for the Arts the Patron; Dean John De Monchaux, Chairman of the Board of Advisors; CAVS director Otto Piene the Chairman of ARTTRANSITION '90, with Lowry Burgess, Elizabeth Goldring and Roger Malina, Senior Consultants and Cynthia Goodman, Conference Director. From October 29 - November 1, over 100 lectures were given, seminars held, exhibitions installed, events performed; ca. 35 artists' presentations addressed the impressive number of international Conference attendants and a live telecommunication video connection permitted a two-way dialogue between Laurie Anderson in Cologne and Otto Piene in the Kresge Theater. Among major contributors were also Rudolf Arnheim, art philosopher and psychologist; environmental artists Christo and Dale Eldred; media artists Charlotte Moorman and Nam June Paik; kinetic artist Wen-Ying Tsai - to name just a few. A video/tv documentary and a special issue of LEONARDO on ARTTRANSITION '90 are currently being prepared. The Conference has further fueled art-and-technology to "spread like brushfire" - as is increasingly evident in the forming and expanding of new, respective institutes and schools throughout the world.

During the '90/'91 academic year CAVS groups and individuals have participated in various US and international events, with an emphasis on activities abroad, because of the renewed strong interest and resulting funding for art-and-technology in countries like Germany, France and Japan. A major CAVS project, with Otto Piene, Paul Earls and Jan Strasfogel its principal artists, was sponsored by CNAT - Centre National Art et Technologie at Reims, France, for the City's "Automnale" festival. "Dialogue de Têtes", a large-scale outdoor multi-media performance involving 40-foot high inflatable heads by Otto Piene, music composed by Paul Earls and played by faculty of the Berklee College of Music, and text and lyrics in two languages by Jan Strasfogel for US/French actors and

singers, were some of the features of the spectacular performed three times to an audience of 50,000. The support crew included a good number of MSVisS graduate students who operated sound and light equipment and inflatables.

Some other examples of CAVS participation:

Environmental, multimedia installation of CAVS, again, at "Images du Futur", Cité des Art et des Nouvelles Technologies, Montreal, with emphasis on laser/music image projections; principal artist, Paul Earls. Several CAVS artists and former CAVS Fellows participated in the Media Park Cologne art concept proposal submitted by Otto Piene - which led to the followup proposal for art objects, programs and installations currently being specified for execution. Fellow Dieter Jung's exhibition and catalog - with contributions by CAVS artists - was presented at the Staatliche Kunsthalle, Berlin.

Academic international collaborations: Kunstakademie für Medien, Cologne; Zentrum für Kunst und Medien, Karlsruhe; UNESCO, Paris; Institute for Fashion and Media, Ochanomizu University, Tokyo; CETECH Institute, Université Paris/Dauphine.

CAVS, with Otto Piene as concept and design director, has continued its collaboration with the Cambridge Redevelopment Authority to realize Stage 1 of "Galaxy", a public art environment on Kendall Square in Cambridge leading to its public dedication, September '90. The "pocket park" has since become a popular feature of the Kendall Square "new landscape". The projected 4 further stages of the project await public and private funding to include technological media in addition to the existing display of natural and built elements.

Educational commitments have included undergraduate-teaching (4.371 Art and the Environment, Otto Piene with Elizabeth Goldring and Paul Earls; 4.385 Poetics of Visual Language for Specific Environments, Elizabeth Goldring and Panos Kouros; 4.389 Environmental Holography, John Powell) and the MSVisS program (Otto Piene), theses: Nathan Hemenway, "Carousel"; Jarlath Waldron, "Accident of Geography"; Zaphos Xagoraris, "The Automaton Theater".

CAVS director Otto Piene has had one-man exhibitions in Düsseldorf ("Licht und Feuer") and Essen. His work is included in "Art in the Sky", an art kite exhibition which is travelling through a series of international museums including the Musée Royal in Brussels and the National Gallery in Berlin. He developed the art concept for Media Park in Cologne and collaborated on its central fountain and public park with Zeidler Roberts Architects, Toronto.

Individual Fellows' activities:

Besides teaching new laser art summer classes at Harvard University, long-time Fellow Paul Earls has installed a lasting laser/music display at the MIT Museum and contributed a laser/music event, "All-Boston Birthday Celebration" on City Hall Plaza for First Night Boston. He is building a permanent Laser Atrium for the new Liberty Science Center off Manhattan.

CAVS exhibits and projects director Elizabeth Goldring is engaged in "Experiments in Retinal Poetry" in collaboration with Senior Scientist Robert Webb of the Boston Eye Research Institute leading, a.o., to a CAVS performance, "Retinal Poetry - Experiments in Visual Language Seen Through the Scanning Laser Ophthalmoscope" (grant from the MIT Council for the Arts).

Fellow (and ARTTRANSITION '90 director) Cynthia Goodman was the curator of a Hans Hoffman retrospective painting exhibition at the Whitney Museum of American Art in New York City. Tal Streeter has been an artist-in-residence at

the Gyewon School of Art in Seoul, Korea. Julean Simon's computer research, "Modulo Topology", has been funded by the Austrian Ministry of Education and Art. Ellen Sebring's art video work has been featured by Studio 7, WCVB-TV, Boston, Channel Seven. Several Fellows and graduate students participated in "Site 2", a Boston reclamation project.

Among CAVS publications, the poetry book, "Center Poems", resulting from a poetry class by Elizabeth Goldring and Panos Kouros, most speakingly represents "Center Spirit"; it unifies lingual and visual contributions by twelve Fellows and former Fellows and seven MSVisS graduate students in a volume made with economic means of production. Tal Streeter and Pam Houk edited "Art that Flies" for Dayton Art Institute Press.

OTTO PIENE

Center for Real Estate Development

The Center for Real Estate Development (CRED), founded in 1984, carries out research and education in real estate development, investment, and management. The Center's principal activities include an 11-month professional degree program leading to a Master of Science in Real Estate Development and a research program on issues related to the planning, development, and management of real estate, including its financial performance.

During its seventh year of operation the Center has continued to build its international relationships through a seminar in Europe for its students and faculty, and increased contacts and travel by members of the faculty. Co-chairman of the Center's Advisory Committee, Luud Maas, President of Wilma International, N.V. was instrumental in arranging an 8-day seminar in June for the CRED graduate students and six members of the faculty. The seminar, with a curriculum organized in cooperation with the University of Amsterdam, enabled students of the Class of 1991 to experience first-hand the booming pre-1992 real estate markets of the Netherlands and Germany, the obverse of the market cycle in effect in the U.S. Linkages were also established or confirmed with academics and members of the real estate industry that will increase opportunities for research and curriculum development on issues of comparative development and investment.

In addition, Center Director, Professor Lawrence Bacow, taught for two weeks at the University of Bari in Italy. Former Center Director, Visiting Professor James McKellar, continued and expanded his work on privatization of housing markets in Eastern Europe. Under the auspices of Habitat, the United Nations Agency for Human Settlement, and the National Association of Realtors, he has been monitoring and encouraging the process of change as the Soviet housing system plans a move away from a demand economy.

EDUCATION

In October, 1990, the sixth class of 31 CRED graduates received their MS degrees in Real Estate Development. Three joint degree students were also members of the Class of '90 and received their MS degrees when they completed their other academic programs. The CRED Class of 1992 was selected from an applicant pool which, though slightly smaller than the previous year's group, was very well qualified. The 39 members of the incoming class include 8 students from outside the U.S.

The MSRED curriculum continues to evolve. Increased emphasis has been placed on portfolio management and investment, managing workouts, and global capital markets, with a corresponding decrease in focus on new development. A new course in portfolio management was added to the core curriculum as an elective, and new units and case studies were added to the finance, law, and management courses to reflect the shift. The curriculum also includes a non-credit but very popular weekly seminar on global capital markets. The thesis seminar, new last year, was presented this year in a concentrated format over two full days.

Another innovation which has strengthened the education program is the establishment of a group of alumni advisors to serve as mentors for the students. They have been effective in providing continuity and perspective to the students as they go through an extremely strenuous academic year.

RESEARCH

Research at the Center continues to investigate various geographic and product markets. Associate Professor William Wheaton and Harvard colleague, Denise DiPasquale, developed a new structural model of U.S. residential markets and completed a study refuting the earlier contention of Harvard economists that overall housing prices were due for a steep decline. Associate Professor Wheaton also produced a study on the role of zoning regulations in land pricing. Professor Bacow wrote an essay on the high price of land in Tokyo, concluding that the barriers to more realistic pricing

were primarily political. Lecturer Marc A. Louargand surveyed the behavior of foreign buyers of residential and investment property in Los Angeles and Atlanta. Other pieces of research done by Center faculty include Lecturer Gloria Schuck's study of the growing outsourcing of the corporate real estate function. Senior Lecturer Michael Wheeler investigated the resolution of siting disputes through the deliberate creation of innovative negotiation forums and procedures. Professors Bacow and McKellar are continuing to work on privatization of housing markets in Eastern Europe.

A new research seminar series, co-sponsored by the Department of Urban Studies and Planning, brought eight academics from other universities to campus in the fall and spring terms to discuss their recent research in the area of real estate.

PROFESSIONAL EDUCATION

The Center's professional education program included the third session of the Minority Developer's Executive Program (MDEP), and the second Pension Real Estate Association (PREA) institute, both taking place on campus in June, as well as the sixth summer of short professional development courses. This year the MDEP expanded to include a number of participants from cities around the country who paid the full cost of the program. As in the past, the majority of attendees were from within the state and were subsidized by contributions from the BRA and the Bank of Boston. Many members of the CRED faculty taught in the course on a pro bono basis. The second session of the PREA institute brought 49 pension fund sponsors and advisors to MIT to study the application of Modern Portfolio Theory to real estate.

The 1990 professional development course offerings included three proven courses which attracted excellent attendance in spite of the poor state of the real estate market. Two of those courses will be given again in July 1991 along with a new course on the uses of MIS in real estate firms. A number of faculty members will take part in that course.

MEMBERSHIP

For the first time the Center suffered a decline in income from member companies due to the distressed conditions of domestic real estate markets. In spite of conditions, 12 firms joined the Center this year, eight of which are national firms or are headquartered outside of New England. They represent the areas of law, consulting, investment and development. As in past years many member firms support the Center in important non-financial ways through taking part in case studies, appearing as guest speakers in classes and in the Rose lunchbox series, and supporting student thesis research.

Semiannual members meetings were held in December and June. The topic for the winter meeting was the impact of governmental policies on real estate development. Professor James Poterba spoke at the evening session on "The Economics and Politics of the Budget Deficit." He was followed the next morning by speakers addressing tax policy, possible reductions in the defense budget, and housing policy. The June meeting focussed on housing research at MIT and featured Visiting Professor McKellar speaking of his recent experience in monitoring the changes in Russian housing policy. Lecturer Schuck also summarized the European seminar and the Center's efforts abroad over the past year.

ADMINISTRATION

Recent changes in the administration of the Center have brought Thomas A. Steele, former President and CEO of Perini Land and Development Company and Perini Investment Properties, to the Center as Chairman as of June 1. He was a founding member of the Center and a member of the advisory committee and has taught in the finance course for many years. He is responsible for industry liaison, resource development, and administration. Honorary Chairman Hank Spaulding, the former Chairman, will remain active in the Center.

LAWRENCE S. BACOW

Media Arts and Sciences Section

The Media Arts and Sciences Section, in its fourth year of operation, is moving toward stabilized operation in its academic programs, largely via the efforts of our Departmental Committee on Graduate Students, and our admissions and degree programs coordinator, Linda G. Peterson. We have been "on-line" long enough that timely prodding of students through the programs is becoming a small concern, and so are exploring new ways of prodding our students along. Our faculty size is a more significant concern, addressed through an ongoing search for six new faculty, which has yielded two new appointments this year. And planning continues for a review of our academic programs in the Fall of 1992, which will undertake an overall look at how we are doing, and where our academic planning should be headed for the longer range future.

EDUCATION:

Graduate:

One hundred and forty-one applications for our graduate program were received this year, from which 25 were selected for admission (including two women and two underrepresented minorities), 12 for the Master's program, and 13 for the Doctoral program. Our graduate student population this year consisted of 76 students (14 women and six underrepresented minorities), of which 39 were in the Master's program and 37 in the Doctoral program, continuing a long-term shift of balance toward the Doctoral program (compared to 44 S.M. and 31 Ph.D. students last year). Twenty-six advanced degrees were awarded during the year (22 S.M. and four Ph.D.). Thirty-seven graduate subjects were offered by the Section this year (no change from last year).

Undergraduate:

This year we offered seven undergraduate subjects (up one from last year). While the Section lacks an official undergraduate academic program, the 89 UROP students active in the Media Laboratory over the year maintained our lively interaction with the undergraduate student body. Of these, many do their undergraduate thesis research under our faculty's supervision. Five subjects were offered during IAP (compared to three last year), involving three of our faculty members.

FACULTY AND STAFF:

New Appointments:

Dr. Pattie Maes was appointed Assistant Professor of Media Technology in June 1991. Dr. Maes received the Doctorate in Computer Science from the Vrije Universiteit Brussels in 1987. Her interests include artificial intelligence, artificial life, and planning and learning algorithms for autonomous machines.

Dr. Rosalind W. Picard was appointed Assistant Professor of Media Technology in June 1991. Dr. Picard received the Sc.D. in Electrical Engineering and Computer Science from MIT in June 1991. Her interests include image and pattern modeling, computer vision, and multi-dimensional signal processing.

A new academic staff position was created this year, a one-year internship as part of a program to widen the entry and preparation opportunities for our academic program, and intended specifically for underrepresented minorities. The first recipient of this internship is Mr. Carlos Alston, who has been working in the Interactive Cinema Group.

Honors & Awards to Faculty Affiliated With the Media Arts & Sciences Section:

Assistant Professor V. Michael Bove, Jr., was awarded the Sony Corporation Career Development Professorship.

Assistant Professor Glorianna Davenport was the co-recipient of MIT's Gyorgy Kepes Prize for 1990, for her work on new forms of interactive cinema.

Associate Professor Tod Machover's compact disk "FLORA" (containing four hyperinstrument pieces) was named "Contemporary Music Recording of the Year 1990" by the Boston Globe.

Associate Professor Alexander P. Pentland and his student, Matthew Turk, were awarded a prize by the IEEE Conference on Computer Vision and Pattern Recognition for their research in face recognition.

STEPHEN A. BENTON

Media Laboratory

INTRODUCTION

The highlight of the year for the Media Laboratory (Media Lab) was its Fifth Birthday celebration on October 1 and 2, 1990, with a major two-day Fifth Anniversary Symposium to a full house at Kresge Auditorium together with gala banquets, receptions and meetings with sponsors and friends of the Lab over the entire week. Over 2,000 faculty, staff, sponsors, students, friends and other guests attended all or part of the Fifth Anniversary events. A smashing booklet was issued commemorating the event around the theme "Being Five."

Alan Kay opened the Symposium with the First Misawa Lecture entitled "What is the Next Computer Revolution." The Misawa Distinguished Lecture Series was established to honor Mr. Chiyogi Misawa for his generous support of the Laboratory through his sponsorship of the Media Lab's accord with Nihon University for collaboration in the planning of a new research institute in Japan — The International Advanced Research & Development Institute (IARDI). The theme of the Misawa Distinguished Lecture Series is "technology and the quality of life" and it will be presented annually.

Just a few months later, on December 19, 1991, a front page story in the New York Times "MIT Deal with Japan Stirs Fears of Competition" was highly critical of the Media Lab's four year old arrangement with Nihon University. That article flamed a furor which led over the next few months to a flurry of articles, interviews, letters to the editors, etc., specifically in explanation of the agreement (initiated by a congressional committee chaired by Representative Richard Gephardt) and more generally of American university/Japan relationships. MIT President Vest summed up his view of this attack on the Media Lab and MIT in the following excerpt from an interview in the May/June 1991 Technology Review:

"The (other) concern is that the Institute and other universities have been subject to criticism for receiving support from other countries, in particular from Japan. The very unfortunate and, in my view, unfair article in the New York Times about the Media Laboratory — while it is an example of the kind of criticism that is out there — is a tempest in a teapot. The Media Lab contract with Nihon University is an example of an agreement in which there was a strong two-way street, and there has been nothing inappropriate about it."

SPONSORS

Media Lab research volume was virtually constant compared to last year — \$7.4 million in FY 1991 versus \$7.5 million in FY 1990 — reflecting the attainment of planned size and capacity for this phase of our growth. General and fund volume in support of Media Lab and Media Arts and Sciences Academic Program grew from \$3.3 million in FY 1990 to \$4.5 million in FY 1991.

Sponsorship grew in several dimensions during the year as summarized by the complete Sponsor List at the end of this section.

New research sponsors during the year included RAI-Radio Televisione Italiana and the German Bundespost, who both joined the Laboratory as new European Sponsors of the TVOT (Television of Tomorrow) Consortium. New members of the Media Technology Group in FY 1991 were British Telecom, Gannett Co., Inc., Knight-Ridder, Inc., Nokia Corporation, and TeleColumbus AG.

IBM signed a three-year continuation of its support of research in multi-media, reflecting that company's strong commitment to this emerging industry. This extension, combined with IBM's support since the inception of the Lab, leaves IBM in the position of the lab's largest cumulative sponsor.

However, for the first time, the Defense Advanced Research Projects Agency (DARPA) became the lab's single largest funder, supporting 17.4% of our work in FY 1991. Three new programs were funded by DARPA this year: perfectly scalable video, 16K bit video, and holographic video. Under the supervision of the Rome Air Force Development Center, DARPA continues to support a general program in advanced mapping techniques.

The year has seen some shrinkage as well as growth. Notably, Hewlett-Packard, AT&T, and General Motors discontinued research support at the Media Lab. While some of this can be attributed to priority and organizational changes in these companies, much is attributable to recession. The Media Lab's large base of industrial support, albeit international, is likely to experience greater turnover in funding than experienced at other labs funded through large scale governmental support.

Equipment gifts during the year from Apple Computer, Digital Equipment Corporation, Hewlett-Packard, and Sun Microsystems benefitted various research groups within the Laboratory.

MAJOR TECHNICAL ACHIEVEMENTS

Amongst the 65 projects listed in this report, each includes achievements. Of special note are four:

- The world's first real-time, moving, synthetic hologram was demonstrated, including shaded and hidden surfaces.
- The concept of scalable video was embodied in a working prototype, which demonstrates a new approach to television, one which is independent of resolution, frame rate, and aspect ratio.
- A 6000-line television display, coarsely, but seamlessly, tiled was demonstrated.
- A theory of common sense and understanding emerged in the context of news personalization and will be the basis of a new initiative: the newspaper of the future.

SPACE

Major space changes completed during the spring and summer of 1990 included:

- Addition of a second floor conference room for Communications and Sponsor Relations (CASR).
- Conversion of the fourth floor equipment cage to office and computer garden space for the Systems Programming Group.
- Conversion of the Beckwith Photo-Graphics Laboratory from wet chemistry to principally digital imaging work as Computer Input/Output Laboratory (with photography equipment transferred to the new Visual Studies space).
- Conversion of the Film/Video Section edit rooms into more open Interactive Cinema research space.
- Conversion of the Film/Video archive space into a central transfer laboratory facility.

In all, some 2,200 square feet was redesigned and renovated under a fast track process managed by MIT's Physical Plant.

CENTRAL COMPUTING

The Lab moved a major part of its computing from a centralized computing facility to distributed computing during the year. The Digital Equipment Corporation (DEC) VAX6310 and associated disks which performed file service for workstations around the building was replaced by eight new DEC server systems. This new configuration moves 90 percent of file server traffic off the network spine. Server MIPS were increased by a factor of 40, installed storage doubled, and storage capacity increased 600 percent.

PERSONNEL

The Communications and Sponsor Relations (CASR) Group experienced a number of staffing changes during the year. Mr. Christopher T. (Chris) Gant joined the group as Associate Director in August, 1990. Chris has an M.B.A. from the Harvard Graduate School of Business Administration and an undergraduate B.A. in English from Haverford College. He was resident in Japan for three years and speaks fluent Japanese. Chris administers the Lab's Japanese operations and will be the founding editor of a new Lab monthly newsletter which will be inaugurated this fall.

Professor Patrick A. Purcell, former Director of CASR, returned to the United Kingdom, as planned in July, 1990 and served as a consultant to the Media Lab during FY 1991 developing, strengthening and coordinating relations with European sponsors. He will continue that activity during FY 1992 although for a smaller percentage of time following acceptance of a Professorship at Ulster University in May.

As the fiscal year draws to a close, the appointment of Mrs. Penny Blaisdell to the position of Director of Communications and Sponsor Relations (CASR) at the Media Lab was announced, effective August 1, 1991. Mrs. Blaisdell is currently the Director of Informations Services at MIT and was formerly a Vice President at Arthur D. Little, Decision Resources. She brings with her a broad base of computer and industrial experience.

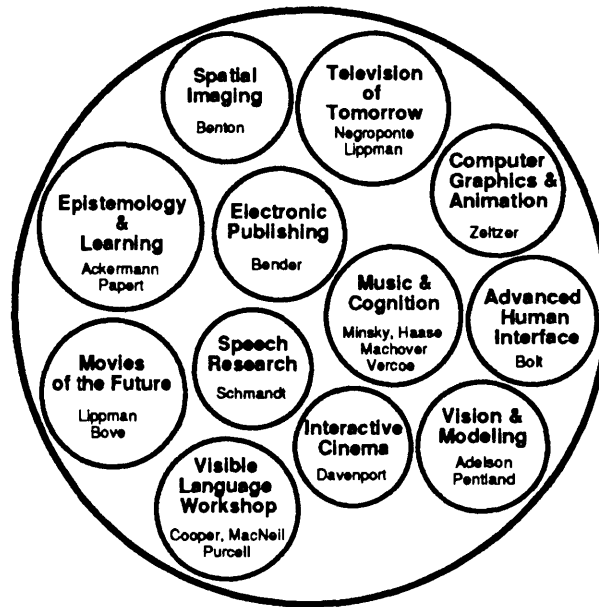
Mrs. Blaisdell succeeds Dr. Harry Stevens, who was with the Lab for one year, during which time he developed a suite of computer programs through which CASR manages visits, publications, and a growing degree of electronic communications with sponsors.

Mr. John Hynes is Acting Director of CASR in July, 1991, continues as intellectual property officer, and manages our liaisons with Europe.

Victoria Vasilopoulos joined the Laboratory in August, 1990 in the newly created position of Executive Assistant and Office Manager of the Director's Office.

Departures from the Media Laboratory in FY 1991 included Mr. Stephen Ocko (part-time Research Scientist) who left to work full-time at Lego Systems; Mr. Philip Pardi (temporary Sponsored Research Staff administrator) who departed to work for an international humanitarian agency in Central America; Mr. Xiang Chen (temporary Research Specialist) who joined Digital Equipment Corporation following his term appointment; Dr. James Davis (temporary Research Associate) who left to work for Xerox Corporation after completing his term appointment; and Mr. Ayisi Makatiani (Research Specialist), who has moved to Integrated Computer Solutions of Cambridge, MA where he works on projects related to the X window system. During his year as a minority intern at the Media Lab, Makatiani gained valuable experience with current Unix software and practice as well as contributing to the Systems Programming Group's network mapping project.

CURRENT RESEARCH



I. SIGNAL PROCESSING

1. Mid-Level Vision
2. X-Y-T Image Analysis
3. Analysis of Shading & Reflectance
4. Movie Datatypes
5. Paperback Movies
6. Combining Multiple Sources of Range & Motion Info
7. Desktop Movies

II. MEDIA TECHNOLOGY

8. Open Architecture Television -- Basic Research
9. Digital Video Network
10. Structural Models of Motion Pictures
11. Perfectly Scalable Video
12. Variables in the Viewing Experience
13. Color Semantics
14. "Paper-Like" Interfaces
15. Wide-Angle Synthetic Holograms
16. Edge-Lit Holograms
17. Holographic Color Control
18. Holographic Video
19. Memory-Based Representation
20. Understanding News
21. Range-Sensing Cameras

III. HUMAN INTERFACE

22. Multi-Modal Natural Dialog
23. Knowledge Based Animation
24. Data Glove
25. Tactile Simulation/Force Feedback Joystick
26. Computers and Telephony
27. Desktop Audio
28. Voice Interfaces to Hand-Held Computers
29. Voice Hypermedia
30. Voice Windows
31. Telephone-Based Voice Services
32. User Modeling

IV. APPLICATIONS OF MEDIA TECHNOLOGY

33. Society of Mind
34. Animal Construction Kits
35. Storyteller Systems
36. Multi-Media Testbed
37. Computationally Expressive Tools
38. Graphical Intelligence
39. Large-Scale, High Resolution Display Prototypes
40. Input/Output Considerations
41. Visual Information System
42. Elastic Movies
43. Electronic Scrapbook
44. New Tools for Directors
45. Context-Based Representation for Video
46. Advanced Interactive Mapping Displays
47. Hyperinstruments
48. Synthetic Holography for CAD
49. Holograms for Medical Imaging
50. Synthetic Performers
51. Synthetic Listeners
52. Synthetic Spaces
53. Cognitive Audio Processing
54. Structured Audio Transmission
55. Looking At People
56. Fractal-Based Bandwidth Image Coding
57. Exploratory Design
58. Constructionism: Elementary Science Education
59. Using Computers to Combat Illiteracy
60. Children as Cyberneticists
61. LEGO/Logo
62. Science and Whole Learning Project
63. Children and Nintendo-Like Games
64. New Images of Programming
65. Headlight Model School

**MEDIA LABORATORY
SPONSORS**
(as of June 30, 1991
and during FY91)

The following list indicates Media Laboratory Sponsors according to the categories of sponsorship defined in *Intellectual Property Rights of the Media Laboratory Sponsors*:

Research Contracts

Apple Computer
AT&T
BNR, Inc.
Columbia Pictures Entertainment, Inc.
Control Data Corporation
DARPA
Deutsche Bundespost Telekom
Eastman Kodak Company
General Motors Corporation
GoldStar
Hewlett-Packard Company
Hughes Aircraft Company
International Business Machines
National Science Foundation
NEC
NHK
Nintendo
NYNEX
PAWS, Inc.
RAI-RadioTelevisione Italiana
SECOM*
Sharp
Sony
Sun Microsystems
Thinking Machines
Toppan
Viacom International
Warner Brothers, Inc.
Yamaha

Media Technology Group

Ameritech
Apple Computer
BellSouth
British Telecom
Citicorp/TTI
Communications Canada/ATEC
CONTEL
Control Data Corporation
Electronic Data Systems/CMI
Fujitsu Laboratories, Ltd.
Gannett Co., Inc.
Hitachi
Hughes Aircraft Company
IRI Group
Knight-Ridder, Inc.
Lotus Development Corporation
McCann-Erickson
MITRE
Mitsubishi Electric
The News Corporation Limited
NOKIA Corporation
Olivetti
Pioneer
Roland
Seiko Epson
System Soft
TeleColumbus AG

Major Building Gifts & Endowment

American Broadcasting Company
Asahi Broadcasting Corporation
Asahi Shimbun Publishing Company
Columbia Pictures Industries
Dow Jones
Eastman Kodak Company
Fukutake Publishing
Hitachi
IARDI
Interlego A/S*
Matsushita
MCA
The Mead Corporation
NEC
Nintendo
Schlumberger
Sony
TIME, Inc.
The Times Mirror
Toshiba*
Warner Communications

Major Equipment Gifts

Apple Computer
Digital Equipment Corporation
Hewlett-Packard
New England Digital
Sony Industrial Products
Sun Microsystems

* has fund agreement in addition

SCHOOL OF ENGINEERING

The School of Engineering underwent a transition in leadership with the appointment of Professor Joel Moses, former head of the Electrical Engineering and Computer Science Department as Dean and Professor David N. Wormley, head of the Mechanical Engineering Department as Associate Dean. Professor Gerald L. Wilson, the former Dean, is spending a sabbatical year at United Technologies. Professor Jack L. Kerrebrock, the former Associate Dean, previously returned to teaching and research in the Aeronautics and Astronautics Department.

The School's major initiatives and concerns have in large measure been continuations of the ones that have occupied it for the past few years.

The Electrical Engineering and Computer Science and Aeronautics and Astronautics Departments have continued to explore plans for Five Year First Professional Degree Programs. Such programs assure a bachelor's degree, usually after four years, and a master's degree after the fifth year.

The Large Scale Systems (LSS) Committee has been reconstituted under the Chairmanship of Professors Joel Moses and Daniel Roos. This Committee has explored, among other issues, Second Professional Degree Programs. Such programs would be offered to students who have worked in industry for three to five years and are interested in becoming managers of relatively large engineering projects. The Leaders for Manufacturing (LFM) program that is run jointly by the Sloan School and the School of Engineering is one such program. The LSS Committee is, in effect, considering broadening aspects of the LFM concept to the entire School of Engineering. The Aeronautics and Astronautics Department is considering a similar Second Professional Degree Program for students interested in systems engineering in that field.

Research on various aspects of the environment is an issue of growing concern at MIT and elsewhere. The Provost has created a Council on Global Environmental Change to coordinate activities in the global change area. The School's faculty is particularly interested in monitoring such global changes, and in technical or policy issues concerning the mitigation of the changes that do occur. A related issue is industrial ecology - a cradle to grave examination of industrial processes with the goal of reducing environmental impact at the same time as reducing overall cost. A third set of issues with which the School's faculty have long been concerned is regional pollution, in particular hazardous waste. Our near-term goal is to find mechanisms to help coordinate the various activities of the School in the environmental area.

Professor Ronald M. Latanision has chaired an Institute Committee on K-12 education. This effort was begun under former Dean Gerald L. Wilson. The Committee submitted its draft report to the Institute's administration toward the end of the academic year.

The EECS Department in cooperation with the Lincoln Laboratory, the Sloan School, the Media Laboratory and the Political Science Department is considering a major initiative in the telecommunications area. The coming of fiber optics connections to every office and home in the coming years will mean a revolution in communication and information services. The goal of this study is to determine the role of the Institute in research on the underlying technology, system software and services.

This year the School of Engineering received several gifts which will be administered through the Dean's Office. Hitachi America, Ltd. provided funds to establish the Hitachi America Professorship. Professor Albert Meyer of the Electrical Engineering and Computer Science Department has been appointed to the Hitachi America Professorship in recognition of his contributions to the theory of computation and programming languages.

The School was notified by General Electric Foundation that it will receive funds for three years to support its program designed to attract women and underrepresented minorities into the engineering faculty.

Funds provided by Edmond Shea ('52) were used by the Dean to support an undergraduate team, Project Olympus. The team is designing and building a rocket capable of launching a payload into low earth orbit in 1993.

AWARDS

The Bose Award for Excellence in Teaching was established last year. It was presented this year to Professor Alvin W. Drake of the Department of Electrical Engineering and Computer Science. Professor Drake was cited for his development of 6.041, his subject in applied probability, some 25 years ago and, despite its overwhelming success, his continued efforts to improve it. Course 6.041 is praised by students, faculty and alumni for the high-level conceptual lectures, for the thoughtfully structured recitation/problem sessions, and for the meticulous and caring effort Professor Drake brings to the organization and administration of this large subject.

Each year Professor Drake selects, mentors and inspires a team of unparalleled teaching assistants which receives consistently high praise in student evaluations and almost every year one of the TA's wins one of the Course 6 annual teaching awards.

Henry Ford II Scholar Award - This award is presented to the seniors in the School of Engineering who have attained the highest academic record at the end of the third year and who have exceptional potential for leadership in the profession of engineering and in society.

The recipients this year were: Sanjeev Agrawal, EECS; Joseph J. Berghammer, Chemical Engineering; Michael M. Goodwin, EECS; Hong-Kwang Kuo, EECS; Stan Y. Liao, EECS; Daniel R. McMahon, EECS; Gregory K. Toth, EECS.

Reinhold Rudenberg Memorial Fund - This prize is awarded to students based on their senior theses in the area of energy conversion.

Because the faculty judged it too difficult to select a clear first place winner, this year's award was presented to three students: Jeff A. Kalt, EECS; Laurette A. Babour, Mechanical Engineering; Derek P. Rutherford, Mechanical Engineering.

ENROLLMENT

Undergraduate enrollment in the School increased last year by nineteen. Undergraduate enrollment in Electrical Engineering and Computer Science increased 7% (54 students). Enrollments also increased in Chemical Engineering (24% - 33 students), in Civil Engineering (13% - 14 students), and in Materials Science and Engineering (5% - 6 students). The number of undergraduates enrolled in ocean Engineering grew from eight to ten. Undergraduate enrollment decreased in Aeronautics and Astronautics (16% - 43 students), in Mechanical Engineering (7% - 34 students), and in Nuclear Engineering (54% - 13 students). Graduate enrollment in the School decreased by 25 (1%), principally in Aero/Astro and in EECS.

ENGINEERING INTERNSHIP PROGRAM

For the summer 1991, 29 sophomores have been placed in the Engineering Internship Program making the total enrollment 95. There are 28 participating companies.

AFFIRMATIVE ACTION

MIT's large numbers of women and black engineering undergraduates relative to other engineering schools was certainly a contributing factor in its successful bid for participation in the Engineering Coalition of Schools for Excellence in Education and Leadership program (ECSEL). The ECSEL program is described in greater detail in the section on faculty below. However, one of the principal goals of the program is to recruit and retain increased numbers of women and minorities in engineering.

Last year, women constituted 20% of all undergraduates in the School. Blacks constituted 8%. Women constitute as much as half of the undergraduates in three departments (Chemical Engineering - 63%, Materials Science and Engineering - 54%, Nuclear Engineering - 50%). Forty-six percent of the undergraduates in Civil Engineering are women. Blacks constitute 11% of the undergraduates in Chemical Engineering, 9% in Aero/Astro and Mechanical Engineering, 8% in Electrical Engineering, 7% in Civil Engineering and in Nuclear Engineering, and 5% in Computer Science.

Recruitment of underrepresented minorities for faculty positions in the School continues to be extremely difficult. There has been no change in the numbers of underrepresented minorities on the School's faculty since last year. Over the past ten years, three underrepresented minorities joined the School's faculty. In the same period, however, three have resigned their positions. Last year the Department of Electrical Engineering and Computer Science offered a faculty position to a black Ph.D. The offer was declined.

The number of women on the School's faculty has grown from ten in 1980 to 18 in 1991. One woman faculty member resigned this year. Another woman will join the faculty in 1992. Yet another woman Ph.D. has accepted a faculty position beginning in 1993.

Over the past ten years, faculty positions have been offered to 190 individuals, 80% (153) of whom accepted those offer. Fifteen percent of the offers were to women, two percent were to black males. Eighteen of the 29 women to whom positions were offered accepted those offers. Two of the three black males to whom positions were offered accepted the offers. The acceptance rate among white males has been over 80% (132 of 158). The acceptance rate among women has been 62% (18 of 29).

Departments in the School continue to monitor the progress of promising women and minority Ph.D.'s at MIT and its sister institutions.

MINORITY INTRODUCTION TO ENGINEERING AND SCIENCE

In the summer of 1991, 55 high school juniors will attend the MITES Program (down from 69 in 1990). The program introduces these students to college level mathematics, physics, humanities, design and chemistry/biochemistry and the MIT atmosphere. They become acquainted with MIT faculty and with each other. The program is directed by A. Douglas Carmichael and coordinated by Mr. William Ramsey.

FACULTY

Faculty Size

Across the School, 16 individuals were named to the faculty including President Charles M. Vest, Professor of Mechanical Engineering and Dr. Paul E. Gray, Professor of Electrical Engineering. With 14 departures, the School's faculty grew by two.

School Professors

Professor Nicholas A. Ashford, Associate Professor of Technology and Policy, published three books in the last year: *Monitoring the Worker for Exposure and Disease* (co-authors Dale B. Hattis, Christine J. Spadafor and Charles C. Caldart), *Chemical Exposures: Low Levels and High Stakes* (co-author Claudia S. Miller); and *Technology, Law and the Working Environment* (co-author Charles C. Caldart).

Professor Louis L. Bucciarelli, Associate Professor of Engineering, was named Director of Program Development for the NSF sponsored Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL). Coalition members include Howard University, City College of New York, Morgan State University, The Pennsylvania State University, the University of Maryland, the University of Washington, and MIT. ECSEL's goals are to increase significantly the number of women and underrepresented minorities among practicing engineers and to increase dramatically the effectiveness of undergraduate engineering education, fostering a curriculum renewal that prepares students for life-long productive careers. MIT will play a central role in ECSEL, focussing on the integration of design throughout the engineering undergraduate curriculum.

Engineering Council

Professor David N. Wormley was named Associate Dean of Engineering. Professor Wormley has served as head of the Department of Mechanical Engineering since 1982. He is succeeded as department head by Professor Nam P. Suh, Ralph E. and Eloise F. Cross Professor of Mechanical Engineering. Professor James R. Melcher, J.A. Stratton Professor of Electrical Engineering and Physics and Director of the Laboratory for Electromagnetic and Electronic Systems (LEES) died in January. Professor Melcher had served as director of LEES since 1985. He is succeeded as lab director by John G. Kassakian, Professor of Electrical Engineering. Professor Kassakian has served as Associate Director of LEES since 1984. Professor Ronald M. Latanision resigned as director of the Materials Processing Center (MPC). He is succeeded as lab director by Professor Thomas W. Eagar, Leaders for Manufacturing Professor of Materials Engineering. Professor Latanision had served as director of the MPC since 1984.

JOEL MOSES

Department of Aeronautics and Astronautics

The 1990-1991 Academic Year was an active one for the Department of Aeronautics and Astronautics. 86 Bachelor's of Science, 59 Master's of Science, 1 Engineer's, and 7 Doctoral degrees were granted. The faculty and their students were actively involved in approximately 200 research projects leading to many discoveries, publications, and presentations. Numerous seminars were presented during the year by visitors, students, and faculty. Under the new Head, the Department gave thoughtful consideration to planning for the future. Not all of these events and accomplishments can be reported in adequate detail, but the highlights for the year are noted in this annual report.

DEPARTMENT STRATEGIC PLAN

A major activity within the Department during the academic year was the development of a comprehensive strategic plan. Several factors converged which precipitated the study. These include global factors of political, economic, and technological change; institutional factors at MIT of a renewed emphasis on undergraduate engineering education; and Departmental factors of the appointment of a new department head and the anticipated hiring of new faculty as a result of a large number of faculty approaching retirement.

A task force representing the Departmental faculty was charged to

Develop a strategic plan for the Aeronautics and Astronautics Department which will establish the priorities for the coming generation. The plan should attempt to portray the Aerospace field in the year 2010, and consider the technological, political, economic, and demographic factors which will shape the field during these twenty years. The task force should recommend areas of research and education which the Department should pursue during the next five years, assign priorities to them, and suggest plans for implementation. The plan should be as thorough as possible, but must be completed by November 30, 1990.

The task force formulated three major questions:

How will the aerospace industry, its customers, its infrastructure, and its constraints evolve over the next 20 years,

What technologies will be critical to the aerospace field over the next 20 years, and

How should MIT educate the next generation of aerospace engineers?

Answers were sought from departmental faculty, over 100 leaders from industry and government, from the current literature, and from the task force members themselves.

The findings from this process were condensed and formed the basis of a mission statement and recommendations for the educational and research programs of the Department. During this process, a number of Departmental issues surfaced related to the life of faculty, students, staff and the diversity of their backgrounds, outreach to secondary schools, and the relationships with other MIT departments and laboratories as well as government and industry organizations. These led to further recommendations. After preparation of a draft report, and discussion and debate engaging the whole Departmental faculty, a final report was completed.

Overall the plan contains 35 recommendations. Some of the major ones are:

The SB degree program should be redesigned to incorporate more mathematics and engineering science fundamentals; subjects on aerospace information, decision, and control; pedagogical approaches utilizing

numerical approaches in addition to analytical methods; and less material on advanced professional subjects.

A new fifth year master's level program, temporarily called the "XM", should be designed to closely fit the revised SB program and provide additional education required for a fully qualified aerospace engineer.

An advanced professional degree, temporarily called the "YM", directed towards educating aerospace systems engineers should be seriously considered.

Major efforts should be undertaken to establish strong research programs in *Aerospace Information, Decision, and Control* and *Engineered Materials*.

Mechanisms must be implemented to improve faculty quality of life for all ranks. The pressures on junior faculty are particularly acute.

A revised undergraduate advising and mentoring program should be implemented to provide an improved educational environment in the Department and a more supportive network for students from diverse backgrounds.

A plan to implement the 35 recommendations was developed and initiated by the end of this academic year.

HUNSAKER PROFESSOR

Professor Satya N. Atluri '69, Regent's Professor at the Georgia Institute of Technology, was the Jerome C. Hunsaker Visiting Professor of Aeronautics for the 1990-91 Academic Year. Professor Atluri is the Director of the Center for Computational Mechanics at Georgia Tech and a well-known expert in fracture mechanics, composite materials, and general structural mechanics. Due to a sudden illness in the spring, Professor Atluri's Minta Martin lecture was postponed until some time in the future.

LESTER GARDNER LECTURE

The Department was honored to have Mr. Willis Hawkins, a retired Vice President of the Lockheed Corporation, deliver this year's Lester Gardner Lecture on April 30, 1991. Mr. Hawkins' talk "Where Have All the Designers Gone" reviewed many important aerospace projects of the past forty years and delivered the warning that today's goals of "zero risk" is stifling the creative engineering process.

FACULTY NOTES

The Department was saddened with the deaths of two colleagues who had been members of the Department for many years. Professors Emeriti Otto Koppen died on January 20, 1991 and Edward S. Taylor passed away on February 2, 1991. Professor Koppen was best known for the design of the helioplane, an early and very successful short take-off and landing aircraft. Professor Taylor was founder of the Gas Turbine Laboratory and a world respected expert in jet propulsion.

Professor Uno Ingard, jointly appointed in the Departments of Physics and Aeronautics and Astronautics, retired at the end of the academic year. The Department appointed three new faculty members during the academic year, Professors Belobaba, Breuer, and McManus, and as of June 30, 1991, had 33 full time faculty members (19 full professors, 7 associate professors, and 7 assistant professors) and three adjunct professors.

Noteworthy accomplishments and milestones of the Departmental faculty include:

Professor Harold "Sandy" Alexander started the Laboratory for Space Teleoperation and Robotics (LSTAR).

Adjunct Professor Richard Battin has received the largest number of major American Institute of Aeronautics and Astronautics (AIAA) awards of any living member. In addition to being elected an Honorary Fellow, these include the Louis Hill Space Transportation Award (now the Goddard Astronautics Award), the Mechanics and Control of Flight Award, the Pendray Aerospace Literature Award, and the von Karman Distinguished Lectureship in Astronautics Award.

Professor Peter Belobaba was appointed to the faculty as an Assistant Professor in the Aeronautical and Astronautical Systems Division on July 1, 1990. Professor Belobaba specializes in air transportation economics and operations analysis, application of quantitative decision methods to aerospace management, and airline and aerospace industry analysis.

Professor Kenneth S. Breuer was appointed to the faculty as an Assistant Professor in the Mechanics and Physics of Fluids Division on September 1, 1990. Professor Breuer specializes in fluid mechanics, stability, transition, and turbulence.

Professor Eugene Covert received the von Karman Medal "in recognition of outstanding contributions to AGARD/NATO."

Professor Edward Crawley received the 1991 Undergraduate Teaching Award from the student chapter of the AIAA.

Professor Mark Drela was promoted to Associate Professor and appointed as the first chairholder of the T. Wilson Professorship of Aeronautics for two years starting January 1991. He was the 1991 recipient of the AIAA Lawrence Sperry Award in recognition "for his contribution of a method to design subsonic airfoils and for his flight demonstrations of his airfoil in Human Powered Aircraft."

Professor Alan Epstein served as acting Director of the Gas Turbine Laboratory and Head of the Propulsion Division during Professor Greitzer's sabbatical.

Professor Edward M. Greitzer was on sabbatical and spent part of the year at Cambridge University as a Visiting Fellow at Peterhouse. He delivered numerous invited lectures in the US and Europe including being a 1990 Lecturer in the Midwest Mechanics Lecture Series.

Professor Steven R. Hall was promoted to Associate Professor.

Professor John Hansman was on sabbatical for the spring semester at ONERA-CERT in Toulouse, France.

Professor Daniel Hastings together with Professor Manuel Martinez-Sanchez started the Space Power and Propulsion Laboratory.

Professor Jack Kerrebrock returned to full-time status to the Department after a sabbatical year at the California Institute of Technology following his five year tenure as Associate Dean of the School of Engineering.

Professor Paul Lagace served as Executive Officer of the Department from June 1990 to May 1991 and as Acting Department Head during Professor Murman's leave of absence in the summer of 1991.

Professor Mårten Landahl received the Daniel and Florence Guggenheim Award from the International Council of the Aeronautical Sciences "In Recognition of his Outstanding Achievements in Aeronautical Sciences". With this recognition, he presented the Daniel and Florence Guggenheim Memorial Lecture on "CFD and Turbulence" in Stockholm, Sweden during September 1990.

Professor Hugh L. N. McManus was appointed as an Assistant Professor in the Structures and Material Division in January 1991. His interests include high temperature materials, advanced composites, thermal structures, and space structures.

Professor Earll M. Murman completed his appointment as Director of Project Athena on May 31, 1991 and took a summer leave of absence. He was elected to the National Academy of Engineering "In Recognition of his Distinguished Contributions to the Broad Fields of Engineering, Engineering Science and Technology".

Professor Amedeo Odoni stepped down as Co-Director of the Operations Research Center and the Statistics Center on June 30, 1991 and returned to full time status in the Department. He was co-recipient with Professor Richard de Neufville of Civil Engineering of the 1990 FAA Administrator's Championship Award for Excellence in Aviation Education.

Adjunct Professor Joseph Shea was inducted as President of the AIAA.

Professor Wallace Vander Velde took over as chair of the Department Doctoral Committee.

Professor Andreas von Flotow received the Department Graduate Teaching Award from the Sigma Gamma Tau Society.

Professor Sheila E. Widnall was reappointed as the Abby Rockefeller Mauzé Professor for another five years.

Professor Laurence R. Young delivered the Ninth Phillip Bard Lecture in Medical Physiology at the Johns Hopkins School of Medicine. The title of his lecture was "Influence on Space Flight On Visual Vestibular Interaction."

UNDERGRADUATE PROGRAM

Undergraduate Enrollment over the Last Eight Years

	1983-4	1984-5	1985-6	1986-7	1987-8	1988-89	1989-90	1990-91
Soph.	100	99	106	120	96	103	75	76
Juniors	81	90	92	103	118	94	87	61
Seniors	81	93	106	98	105	130	104	104
Totals	262	282	304	321	319	327	266	241
% of women	19%	18%	18%	16%	19%	21%	25%	23%
% of underrep. minority students	10%	10%	11%	10%	N/A	14%	18%	20%

Mr. Andrew Lewin '91 was selected for the Doolittle Scholarship Award. His outstanding academic record and contributions to the department made him the successful candidate.

Other undergraduate awards are listed below:

HENRY WEBB SALISBURY AWARD

This award established in the memory of Henry Webb Salisbury ('33) is given annually to a graduating senior in Course 16 for the highest degree of academic achievement. This year's winner is:

Esteban R. Torres '91

JAMES MEANS MEMORIAL PRIZE

For excellence in Flight Vehicle Engineering

Brett P. Masters '91

For excellence in Space Systems Engineering

Gregory G. Loboda '91

ADMIRAL LUIS DE FLOREZ AWARD

Awarded to undergraduates who have demonstrated "original thinking or ingenuity" in Aeronautics and Astronautics. This year's winners are:

Jeffrey T. Evernham '91

William E. Gorgen '91

Marc A. Schafer '91

UNIFIED ENGINEERING AWARD

For outstanding devotion to and leadership of the team of student assistants in Unified Engineering, as well as skillful organization and planning to achieve smooth operation of the complex Unified Engineering enterprise.

Andrew W. Lewin '91

Mark E. Lundstrom '91

ANDREW G. MORSA '87 AWARD

For demonstrated ingenuity and initiative in the application of computers to the field of aeronautics and astronautics

No Winners for 1990-91

LEADERS FOR MANUFACTURING UNDERGRADUATE PRIZE

For demonstration of the relation between manufacturing and technical performance through determination of the influence of manufacturing irregularities on the aerodynamic performance of airfoils.

Marc J. Amar '92

Ramon H. Cajina '92

Robert Fong '92

Natalie S. Henry '92

GRADUATE PROGRAM

A total of 265 applications were received for the Fall 1990 term. Out of this number, 128 were admitted and 57 accepted the offer of admission. Enrollment for Fall 1990 included 141 S.M., 67 Ph.D., and 1 E.A.A. degree candidates for a total of 209. There were 4 minority students (2 S.M., 2 Ph.D.), and 18 women (14 S.M., 4 Ph.D.). In the Spring term, there were 6 new graduate students out of 10 admitted from 27 applications received. Four women applied, 2 were admitted, and 1 enrolled with an RA. One minority applied, was admitted and enrolled with a Draper Fellowship. Enrollment for Spring 1991 was 198 including 126 S.M., 71 Ph.D., and 1 E.A.A. degree candidates. There were 5 minority students (3 S.M., 2 Ph.D.) and 14 women (10 S.M., 4 Ph.D.). Seven Ph.D. (no women or minority students) and 59 S.M. (6 women and no minority), and 1 E.A.A. degrees were awarded in 1990-91.

Funding for graduate students is summarized in the table below.

<u>Funding</u>	<u>Fall 1990</u>	<u>Spring 1991</u>
DOD Fellows	5	5
NSF Fellows	5	5
AFRAPT Fellows	11	11
Other Fellows (Dept., Space Grant, Outside Minority)	4	4
Draper Fellows	30	25
Research Assistants	110	95
Teaching Assistants	10	11
Totals	175	156

JOHN AND IRENE M. GOLDSMITH SCHOLARSHIP FUND

The Department was fortunate to receive a \$612,118.00 bequeath from the estate of Irene M. Goldsmith to endow a Graduate Scholarship. The first recipient will be named next academic year.

RESEARCH LABORATORIES**Aeronautical Systems Laboratory (ASL)**

Director: Professor John Hansman

The work within the Aeronautical Systems Laboratory over the past year has focused in the areas of cockpit information management, automated planning systems and hazardous weather avoidance. The information management activities include studies of situational awareness in the dissemination of hazardous weather alerts, ATC clearance amendments, and in using digital datalinks and evaluation of information requirements for advanced electronic instrument approach charts. These studies have made extensive use of the Boeing 757/767 rapid prototype part task simulation facility which has been developed in the laboratory. The facility replicates the autoflight systems of current generation commercial aircraft and allows rapid prototyping of advanced information displays. The hazardous weather avoidance activities have focused on microburst and ice accretion alerting systems as well as fundamental aircraft ice accretion studies.

Computational Fluid Dynamics Laboratory (CFDL)

Director: Professor Michael Giles

Fourteen graduate students, four faculty and a research engineer are developing and applying methods for the computational modelling of aircraft, rotorcraft and turbomachinery flows. The highlight of the year

was the presentation of the AIAA Lawrence Sperry Award to Prof. Mark Drela for his work with Prof. Michael Giles on the development of an airfoil design method, and his use of the method to design the airfoils for the record-setting Daedalus human-powered aircraft.

Prof. Kenny Breuer joined the CFDL in September 1990. His research centers on the computation of flow instabilities and turbulent structures, and he will also be developing an experimental facility.

A new research initiative began this year in the computation of three-dimensional unsteady flows in multi-stage turbomachinery. The ultimate objective of this work is the calculation of the entire compressor or turbine sections of gas turbine engines. New work is also beginning with Boeing on the inclusion of a coupled boundary layer analysis into their new three-dimensional design and analysis system.

FLIGHT TRANSPORTATION LABORATORY (FTL)

Director: Professor Robert Simpson

FTL research continues in two main areas: airline automation and air traffic control (ATC). In the airline area, we are working with Delta, Northwest, and Air Canada to develop automated scheduling systems for airline planning and operations, as well as testing better airline demand modeling and revenue optimization systems. Swissair and Aeromexico joined the FTL/Industry Cooperative Research Program during the past year. On a grant from NASA Langley, we have undertaken industry studies to foresee the application of advanced technology to capacity improvements in the U.S. aviation system. A small study is underway funded by R. Dixon Speas, a 1938 graduate of the department, to determine trends in the changing nature of the U.S. domestic airline industry since 1978.

In the ATC area, work is underway to transfer and refine the object-oriented ATC simulation technology developed in the laboratory to DLR in Braunschweig, Germany for their work in automated control over vehicles on the airport surface. Lyman Hazelton finished his Ph.D. thesis on expert systems for temporal planning with an application to runway configuration management. Work with Lincoln Laboratories continues on automated decision systems for metering and spacing of aircraft in the terminal airspace, and an interactive tool to assist controllers in the spacing of landing aircraft has been developed. We are currently creating a methodology to establish safe spacings between aircraft with improved surveillance in oceanic airspace for the FAA Technical Center, Atlantic City.

Gas Turbine Laboratory (GTL)

Director: Professor Edward Greitzer

Approximately 35 graduate students are carrying out a broad range of experimental and numerical/theoretical research in the Gas Turbine Laboratory (research budget of roughly \$3.4 million). A multi-disciplinary area where the lab is a world leader is the concept of "smart engines" in which the components are under local feedback control. One specific application is the active stabilization of compressor stall which was successfully demonstrated on an axial compressor this year for the first time ever-realizing a performance gain equivalent to a 10% savings in aircraft weight. A new theoretical development offers insight in turbomachinery tip flows, an area of greatly increased effort. The Laboratory is a strong contributor in computational fluid dynamics as applied to high performance propulsion systems, not only in innovative algorithm development, but also in the use of CFD to increase basic understanding of flow physics and experimental results. Examples of the latter being developed or implemented during the current year are software for numerical flow visualization, three-dimensional rotor-stator interactions in high speed machines, and three-dimensional turbomachine tip clearance flows. This work is done with the Computational Fluid Dynamics Laboratory.

Laboratory for Space Teleoperation and Robotics (LSTAR)

Director: Professor Harold Alexander

The Laboratory, renamed from the Space Systems Laboratory, continued its teleoperation research after the departure of Professor Akin, with a renewed focus on virtual-environment investigation of teleoperator interfaces and on autonomous remote-vehicle control for assisting human teleoperation. An advanced virtual environment system has been developed that permits testing a variety of sensory and control interface designs with human subjects under very well-controlled experimental conditions. On the neutral-buoyancy side, the Laboratory is nearing completion of a new vehicle named Starfish that combines improved computer, power, servicing, and drive systems and that will permit developing and testing advanced autonomous control systems. The machine-vision research to support this autonomous control has led to completion of a thesis on Kalman-filter-based image feature tracking for vision. Two more graduating students have investigated the design of remote vision systems and vehicle-control systems in virtual-environment experiments using human subjects and one more, the prime mover on the new vehicle project, will discuss the first control systems to use its new computational and sensing facilities. Six UROPers have been involved in the Laboratory as well, in a variety of practical activities in support of both virtual-environment and neutral-buoyancy research.

Man Vehicle Laboratory (MVL)

Director: Professor Laurence R. Young

During the past academic year, the Man Vehicle Laboratory has been immersed in preparations for several upcoming, long postponed, Shuttle experiments. The flight of the first dedicated Space Life Sciences (SLS-1) mission, scheduled for May, 1991, has involved most members of the laboratory, from professors through UROP students. Multiple crew training, data collection, and integrated simulation activities have been held at the Johnson Space Center. The first International Microgravity Laboratory (IML-1) scheduled for the end of 1991 includes a human performance and anthropometry experiment which Professor Alexander took over from Professor Bussolari and a test of the vestibulo-ocular reflex under the direction of Dr. Oman. The year has also seen several major moves, and upgrades of some of our equipment. Personnel changes saw Dr. Daniel Merfeld join us as Project Scientist on our Spacelab projects, and Dr. Bhatnagar of the [PI] project leave to join Contel. The Laboratory has 10 graduate students, 3 from other departments, and 14 undergraduate students. The annual budget is approximately \$800,000.

Space Engineering Research Center (SERC)

Director: Professor Edward F. Crawley

The objective of the Space Engineering Research Center is to develop and disseminate a unified technology of controlled structures. In this past academic year, the size and scope of SERC continued to grow. The highlight of the year was the preparation of SERC's first Shuttle flight experiments, called MODE, for the Mid-deck 0-G Dynamics Experiment. The experiment is scheduled to fly on STS 48, in September of 1991. It will require two full days of crew activity, and will test the influence of 0-gravity on the dynamic behavior of fluid in tanks and truss structures. This year SERC was also awarded the Mid-deck Active Control (MACE) experiment, which is scheduled for 1994, as a second Space Shuttle experiment. During the year, the 3.5 meter tetrahedral truss interferometer testbed of the Center was commissioned. The objective of this test article program is to develop the technology to control precision metering trusses down to 50 nanometer, in order to enable large diameter optical instruments in space. Other notable events during the year include the testing at the Johnson Space Center of an input command shaping algorithm developed in SERC, which will be used to reduce the vibration in the Shuttle Remote Manipulator system. In addition, there was continued evolution of the concept of intelligent structures, including in this past year the first successful embedding of a microelectronic component into a structural element. Nine faculty and thirty-five graduate students and a like number of UROPers participate in the activities of SERC, drawn from the Departments of Aeronautics and Astronautics, Electrical Engineering and Computer Science, and Mechanical Engineering.

MIT Space Grant Program

Director: Professor Daniel Hastings

In the second year of operation the MIT Space Grant Program grew in several significant ways. Charles Stark Draper Laboratory was brought in as a consortium partner while JPL and NASA Goddard were added as participants in the program. This brings the total number of participating companies, laboratories and government centers to 12. At the K-12 level, the Program developed a set of videotapes for distribution to schools and, in conjunction with the student chapter of the AIAA, started a program to visit local area middle and high schools to present information on aerospace as a field of study. The Program also worked with the MITES program and developed a Space Design workshop. The seminar, 16.S26, was offered again to 34 students and included a trip to MIT Lincoln Lab and Raytheon. In order to respond to the need for better student mentoring, the Program has established "focus" groups so that students and faculty can get to know each other well. Finally, in a highlight of the spring semester, the Program sponsored a well attended public lecture by Mr. Norman Augustine, CEO of Martin Marietta and Chairman of the President's Advisory Committee on the future of the US Space Program.

Space Power and Propulsion Laboratory (SPPL)

Co-Directors: Professors Daniel Hastings and Manuel Martinez-Sanchez

Approximately 15 SM and Ph.D students with two faculty are carrying out a broad range of numerical/theoretical and data analysis tasks in the area of electric propulsion and the effect of the space environment on space power and propulsion systems. In the field of electric propulsion, a major advance was made this year with the development of a theoretical understanding of performance limiting instabilities in magnetoplasmadynamic thrusters. This theory development credibly explains a diverse body of data. The theory is now being extended to numerical simulations and will be tested on Air Force Lab facilities. A new theory has been developed to explain arcing on high voltage solar arrays in the space environment. The theory is the first in the world which can explain the existing data. As a result of this development, members of the SPPL have been asked to participate in an Air Force flight experiment and a Japanese flight experiment.

Technology Laboratory for Advanced Composites (TELAC)

Director: Professor Paul A. Lagace

Over 35 students were involved with TELAC during the July, 1990 to June, 1991 time period. This included 14 graduate students, 18 UROPers, and a number of students in 16.621/2 who performed their projects in TELAC. Five students finished their master's theses in the laboratory during this period, and the laboratory issued a total of 19 reports, including a number accepted for publication in journals and proceedings. Major research accomplishments during the year include the understanding of mechanisms for damage propagation and potential damage arrest in composites structures, demonstration of a scheme to increase the life of composite laminates subjected to cyclic loads, and an increased understanding of the damage resistance properties of composites and their structures. No new facilities were built or acquired, but current facilities continue to be updated. This includes our unique impact facility which stands as the most versatile one of its kind available. The conversion to Macintosh computers is virtually complete with the testing machine facility now controlled by Macintosh (including data acquisition). A Macintosh has also been used in TELAC's high speed data acquisition facility (up to 10^6 Hertz). Unfortunately, the laboratory has been hampered by two major computer thefts during the latter half of the year and has not recovered (in actual computers or financially) from this loss. A new system for the documentation of computer software generated in the laboratory has been put in place and this makes the distribution of TELAC software easier. As a final note, Assistant Professor Hugh McManus brought the total number of faculty associated with the laboratory to four when he arrived in January. He is just beginning to formulate a research program and has started work with his first graduate student.

Wright Brothers Facility (WBF)

Director: Professor Eugene Covert

This year the operation of the Wright Brothers Facility has involved one graduate student and four undergraduates. Of a total of four different major wind tunnel programs, there were two pedestrian level wind studies. A basic study of the effects of snow and Reynolds number on the galloping response of cylinders for the Raytheon Company was continued from last year. Frank H. Durgin, Associate Director of WBF, is chairman of an ASCE task committee bringing the current standards for wind tunnel testing up-to-date. Finally it should be noted that the results of a series of Boston Redevelopment Authority (BRA) wind tunnel tests in the 1980's, which measured pedestrian level winds, are being implemented as part of the requirements to be satisfied prior to being given a building permit by the BRA.

EARLL M. MURMAN

Department of Chemical Engineering

The 1990-1991 academic year was marked by a number of significant developments in teaching, research, fund raising, and faculty recruiting. These events are summarized here; several of the initiatives are described in more detail elsewhere in this document.

The most significant initiatives in the department revolve around changes in our approach to and attitude toward undergraduate education. Two changes are being implemented. In the first, the faculty agreed unanimously that only faculty members would teach recitation sections in undergraduate subjects, thereby removing teaching assistants from this role. This change represents a very significant time commitment by our faculty and should improve our teaching effectiveness. The cost in labor for the increased teaching load is significant, especially in the face of increasing enrollments over the last four years.

Starting with a day-long faculty retreat in January and continuing with the work of an Ad-Hoc Committee chaired by Professor Robert E. Cohen, the department began an extensive review of the chemistry content of our curriculum. This review was spurred by the overwhelming sense of the faculty that a deep knowledge of organic and physical chemistry is a mainstay of the chemical engineering profession and that our program is seriously lacking in this regard. Our Visiting Committee agreed with this assessment during their meeting in early March. However, solutions to the problem are not easily found while abiding by the Institute's limits on the number of required units in our curriculum. Based on the recommendations of our Ad-Hoc Committee, the department will propose an ambitious set of changes to our curriculum that include teaching two required six unit subjects only during the Independent Activities Period (IAP). The changes to our curriculum are described in more detail below.

Our graduate programs continue to operate at a high level of activity and to attract the very best students from around the world. This year 32 doctoral degrees were awarded, along with 37 master's degrees from the David H. Koch School of Chemical Engineering Practice. The Practice School began operation of a new station at Merck in West Point, New York, and closed the station at General Electric in Albany, New York after 13 years of operation.

Two events in our graduate research program are especially significant. First, the funding of the Biotechnology Process Engineering Center (BPEC) was renewed for a second five years as an Engineering Research Center (ERC) by the National Science Foundation (NSF). The BPEC is directed by Professor Daniel I.C. Wang and involves research by five other faculty in the Chemical Engineering Department. MIT was also awarded a grant from the Alfred P. Sloan Foundation to study the pharmaceutical industry. This program is collaborative between our department and the Sloan School of Management and represents the first significant collaboration between these two units.

Fund raising in the department continued for graduate fellowships from both alumni and industry. A donation from Keith and Helen Rumbel established a graduate fellowship in their names. The department formalized its program for term support of fellowships from industry and started a vigorous campaign to raise additional money from companies here and abroad. So far the returns have been gratifying with commitments for four new fellowships this year.

This year the department had a disproportionate activity in recruiting junior faculty, leading to the hiring of three new faculty members: Professor Linda G. Cima, Dr. Gregory C. Rutledge, and Dr. Jackie Y. Ying. Professor Cima's research interests are in the design and application of biomaterials for cellular transplant. She has a joint appointment with the Whitaker College of Health Sciences and Technology (HST), and was awarded a Presidential Young Investigator (PYI) Award from the NSF this spring. Dr. Rutledge's expertise is in polymer physics, especially in the molecular-scale simulation of mechanical properties of crystalline polymers. He will join us this fall after completing a postdoctoral year at the University of Leeds. Dr. Ying's research and teaching interests are in catalysis and preparation of amorphous and nanocrystalline oxides materials. She just completed a doctorate in Chemical Engineering from Princeton and will spend a postdoctoral year in Germany before joining the department in Fall 1992.

Several departmental faculty received special recognition. Professor Robert S. Langer won the Professional Progress Award from the American Institute of Chemical Engineers (AIChE) and the Clemson Award for Basic Research from the Society of Biomaterials, and Professor James Wei received the Founders Award, also from the AIChE. In addition, Professor Robert A. Brown, Head of the Department, was elected to the National Academy of Engineering. Professor James Wei took retirement from MIT to become Dean of Engineering at Princeton University.

UNDERGRADUATE EDUCATION

The following table shows the trends in undergraduate enrollment:

	86-87	87-88	88-89	89-90	90-91
Sophomore	43	38	47	60	67
Junior	49	36	36	46	60
Senior	65	55	47	34	47
TOTAL	157	129	140	140	174

The sophomore enrollment continues to rise with the result that the total undergraduate enrollment in Chemical Engineering jumped 24% to 174. A particularly interesting aspect of this increasing enrollment is the large fraction of women who are choosing Chemical Engineering. This past year's sophomore class was 67% women; the junior and senior classes are around 60% women, so that our total undergraduate population is well over half women. We are encouraged by our ability to attract top quality female students to our department.

The increasing number of undergraduate students has presented a challenge to the department to maintain small class sizes and close contact between the undergraduates and faculty while continuing our efforts to improve the quality of our curriculum. In January, the department faculty met at the Endicott House to explore our teaching style and the curriculum. Several significant changes were initiated at this meeting. In addition to department commitment to full involvement in the advising and teaching of undergraduates, including full faculty staffing of all recitation sections of classes, we initiated reviews of the chemistry content of our curriculum and of the use of humanities electives by our undergraduates. The results of the chemistry discussions are described below.

Major progress continues in integrating computing into Chemical Engineering subjects and in revitalization of the undergraduate laboratories. A major gift from Air Products of equipment allowed us to add a large scale pressure swing absorption experiment to the undergraduate projects laboratory this year. This work is being carried out under the direction of Professor Jeffrey Feerer. A second project that Professor Feerer supervised this past Fall for the projects lab was the development of new coating technology for M&M's. This research was well received by the sponsor and by the many students and staff around MIT who got to taste the results of the research. New computing initiatives in the undergraduate curriculum this past year included the porting of a process design program to Athena and the addition of a graphically based program for modeling the cleanup of a superfund toxic waste site. Both of the programs are key components in the teaching of our senior level Integrated Chemical Engineering subjects 10.361 and 10.362.

Chemistry in Chemical Engineering

This past spring semester a major study was undertaken on the chemistry component of the chemical engineering curriculum by a committee under the direction of Professor Robert E. Cohen. The committee has suggested the following changes in our departmental requirements and electives in order to strengthen the chemistry foundation of the chemical engineering curriculum:

- Add 5.60 (Physical Chemistry) as a required subject
- Add 5.13 (Organic Chemistry) as a required subject
- Remove 10.14 (Chemical Engineering Thermodynamics II) from the curriculum; quantum chemistry will no longer appear as a topic in any required subject
- Revise 10.21 (Properties of Matter) to include a meaningful amount (1/2 term) of quantum mechanics
- Revise 10.13 (Chemical Engineering Thermodynamics) to build specifically on the thermodynamics taught in 5.60
- Revise 10.37 (Chemical Reactor Design) to build on the chemical kinetics taught in 5.60
- Add a three or six unit version of 5.121 (Organic Chemistry Laboratory) during IAP

We feel that the added exposure to chemistry in the Chemistry Department will provide a useful base on which our students can build a chemical engineering perspective.

The committee has reported back to the Chemical Engineering faculty and received a favorable response on its recommendations. The faculty will act on detailed implementations of these proposals next fall. The committee was particularly gratified in its deliberations by the willingness of the Chemistry Department to discuss changes and to accommodate Chemical Engineering Department needs.

GRADUATE EDUCATION

The following table shows graduate enrollment from 1986-1991:

	86-87	87-88	88-89	89-90	90-91
Masters	77	65	54	62	59
Doctoral	151	169	179	158	164
TOTAL	227	234	233	220	223

The total for 1990-91 includes 86 foreign students, 46 female students, and 12 minority students (not including Asian Americans).

The total for 1990-91 includes 86 foreign students, 46 female students, and 12 minority students (not including Asian Americans). Graduate admissions data indicate suggest that graduate enrollment will remain in the 220 - 230 level for the next several years.

David H. Koch School of Chemical Engineering Practice

This year 26 students participated in the Practice School program at three stations: Dow Chemical at Midland, Michigan; General Electric at Albany, New York; and Chevron at Richmond, California. This summer we have students at the Richmond Station for the third time. The Albany Station was closed in May, and a new station is being opened at Merck in West Point, Pennsylvania over the summer. This new station will provide the important topical focus on biotechnology required by our students. Directors and Assistant Directors for the Stations were: Midland Station - Professor Paul Webley and Mr. Victor Barocas; Albany Station - Professor Keith Bailey and Mr. Philippe Matthys; Richmond Station - Professor Fred Vorhis and Mr. Matthys. Professor Bailey is currently setting up the West Point Station. Professors T. Alan Hatton and Jeffrey L. Feerer continue to direct the Practice School from Cambridge.

Mr. John Mattill, formerly Editor-in-Chief of the *Technology Review* has been commissioned to write a history of the Practice School. This is nearing completion and should be ready for distribution at the 75th Anniversary Celebration of the Practice School in October, at which we will be holding a mini-symposium, banquet, and dance.

The Endowment Campaign was completed with a generous donation from Mr. David H. Koch of Koch Industries; to recognize his contribution, the school has been renamed in his honor. A dinner was held September 26, 1990 to celebrate the completion of the endowment and to honor Mr. Koch and other major donors to the Practice School.

FACULTY NOTES

Professor János M. Beér was invited lecturer at the European Natural Gas Research Conference in Trondheim, Norway, and was invited to be a Distinguished IBM Visiting Professor at Northeastern University in 1990. In 1991, Professor Beér was elected an Honorary Member of the newly established Hungarian Academy of Engineering and the International Flame Research Foundation in the Netherlands has elected him Honorary Superintendent of Research.

Professor Daniel Blankschtein was promoted to Associate Professor in July of 1990. He received the 1991 Chemical Engineering Department Outstanding Faculty Award from the departmental Graduate Student Council.

Professor Howard Brenner chaired sessions on Multiphase Systems at the First Inter-American Conference of Rheology in Montreal and Multiphase Flow at the Eighth Symposium on Energy Engineering Sciences at the Argonne National Laboratory. He was also a Distinguished Lecturer at Clarkson University.

Professor Robert A. Brown was recently elected to the National Academy of Engineering, in addition to being chosen one of the 1991 Outstanding Young Texas Exes, for outstanding alumni/ae from the University of Texas. He was an invited speaker at the annual meeting of the American Association of Crystal Growth in Vail, Colorado, in July of 1990 and the plenary speaker for the Canadian Institute of Metals meeting in August of 1990. He will become one of two United States editors of *Chemical Engineering Science* beginning in July of 1991.

Professor Clark K. Colton was a plenary speaker at the ACS Symposium on Polymers as Biomaterials honoring his former student, Professor Robert S. Langer, in Boston. He was an invited speaker at the UCLA Molecular Biology Symposium on Tissue Engineering, and at the Gordon Conference on Synthetic Membranes.

Professor Charles L. Cooney is regional editor of a new international journal, *Bioseparations*, and is the series editor for a collection of books in Bioprocess Engineering to be published by Butterworth. Professor Cooney also is the Director of the Program on the Pharmaceutical Industry, a new multischool initiative of MIT recently funded by the Alfred P. Sloan Foundation.

Professor T. Alan Hatton was the invited keynote speaker at the Engineering Foundation Conference on Reaction Engineering in Santa Barbara and the invited plenary speaker for ISEC '90 (International Solvent Extraction Conference '90) in Kyoto, Japan in July of 1990. In August of 1990 Professor Hatton served as chairman of the Gordon Conference on Separation and Purification.

Professor Klavs F. Jensen gave invited lectures on the processing of electronic materials by chemical vapor deposition at the Meetings of the Materials Research Society, the American Vacuum Society, and the Electrochemical Society.

Professor Robert S. Langer received the Creative Polymer Chemistry Award from the American Chemical Society in 1989; the Polymer Division of the ACS held a 3 day meeting in his honor at the 1990 National Meeting in Boston. He also received the Professional Progress Award from the American Institute of Chemical Engineers and the Clemson Award for Basic Research from the Society for Biomaterials. Professor Langer gave the Keynote lecture at the Tissue Engineering UCLA Symposia in Keystone, Colorado.

Professor Edward W. Merrill received the Clemson Award for Contributions to the Biomaterials Literature.

Professor Charles N. Satterfield has completed the second edition of his book Heterogeneous Catalysis in Industrial Practice which was published in March 1991. Professor Satterfield was also appointed to the Editorial Advisory Board of the journal *Energy & Fuels*.

Professor Kenneth A. Smith returned to the department after serving for 11 years as Associate Provost and Vice President for Research.

Professor George Stephanopoulos was elected a Foreign Member of the Russian Academy of Technological Sciences and was the Texas Distinguished Faculty Lecturer at the University of Texas, both in April 1991. He will serve as Chairman of the International Programming Committee of the IFAC Symposium on Fault Diagnosis and Supervision of Process Operations to be held in April 1992.

Professor Gregory Stephanopoulos was elected Vice Chairman of the FPBE Division of AIChE; he will chair the Division in 1992. Professor Stephanopoulos was appointed to the chair of the 5th International Symposium of Computer Applications to Fermentation Technology planned for 1992 in Keystone, Colorado.

Professor Daniel I.C. Wang was invited to join the National Biotechnology Policy Board of the NIH for 1990-1993. In addition, his doctoral student Jeff L. Cleland was given the W.H. Peterson Award for best student paper at the National Meeting of the American Chemical Society; this is the twelfth year in succession that this award has been won by an MIT graduate student.

Professor James Wei received the Founder's Award of the American Institute of Chemical Engineers at the national meeting in November 1990. In July 1991, he took early retirement to assume the position of Dean of Engineering at Princeton University.

RESEARCH HIGHLIGHTS

Polymers

The commercial-scale use of polymeric membranes in gas separation processes has grown substantially over the past decade. Professor Robert E. Cohen has been exploring molecular-level and morphological mechanisms for gas diffusion and solubility in a variety of novel membrane systems produced in his laboratory. Oriented block copolymers, halogenated skin-core homopolymers and block copolymers and a new type of microporous block copolymer are being studied. Ferroelectric liquid crystalline polymers are candidates for 'switchable' membranes whose gas permeation characteristics can be modified on-line via the application of electric fields.

In collaboration with Professors Schrock and Silbey of Chemistry and Rubner of Materials Science and Engineering, Professor Cohen has been using ring opening metathesis polymerization to produce block copolymers with potential utility in a variety of electro-optical applications. These include nano-scale semiconductor clusters for optical switches, nano-scale clusters of metals (Pd or Pt) for electromagnetic shielding, and self-assembled and Langmuir-Blodgett assembled layered structures of conducting polyacetylene and insulating polymers for dielectric and other device applications. A unique set of well-characterized polymers is being used in collaboration with a group at CNET in Paris to examine the effect of conjugation length on the non-linear optical properties of these materials.

Optoelectronic Materials

Numerous chemical reactions involving hydrogen have been proposed to affect optoelectronic properties but have been difficult to verify experimentally. In the laboratory of Professor Karen K. Gleason, non-destructive and quantitative measurements of low hydrogen concentrations in solids are being made by nuclear magnetic resonance (NMR) in order to directly explore these property-processing relationships.

Concentrations ~ 0.1 at. % H have been detected in a 500 Å thick thermal silicon dioxide film, where the concentration and bonding environment of hydrogen are keys to determining the mechanism of electronic defect passivation. In bulk SiO₂, used as lens material in excimer laser lithography, a new defect was detected. Identified as a pair of hydroxyl groups, this desirable defect increases the lifetime of a fused silica lens. Although annealing is required to produce a lens of uniform density, this process also destroys the hydroxyl pair. The observed reaction product of annealing is a trapped water molecule. Other chemical processes which maintain the desired concentration of hydroxyl pairs while also providing uniform density are under investigation.

Hydrogen incorporated into polycrystalline diamond films was found to be influenced both the diamond deposition process and resultant material properties. Hydrogen was found to have a large influence on the optical absorbance in the 8 to 10 μm wavelength region, thus effecting the diamond film's performance as an infrared window. Although average concentrations are <0.25 at.% H, segregation produces regions of extremely high local hydrogen density (>35.0 at.%), most likely at grain boundaries. The majority of hydrogen is rigidly held, although rotating methyl groups were observed at room temperature. By altering deposition conditions, films with no detectable hydrogen (<0.001 at.%) and good optical transparency were produced.

Environmental Engineering

Concern with the environment pervades much of the department's research with activities directed at pollution prevention by product and process reformulation, the characterization and control of emissions, and the remediation of existing waste sites. The discussion here will be restricted to the research programs on combustion, which is both a source of contamination and a means of reducing wastes through incineration. Studies, under Professors Beér, Howard, Longwell, Sarofim and Dr. Flytzani-Stephanopoulos, have been largely conducted on small scale equipment designed to examine the mechanism and kinetics of formation of organic pollutants such as the polycyclic aromatic hydrocarbons and soot, aerosols enriched in toxic metals, nitric oxide, and sulfur oxides. The fundamental studies have been used to guide the development of control and monitoring strategies, which have been demonstrated, under the direction of Prof. Beér, on the pilot scale 3 MW_t MIT Combustion Research Facility. Although the most economic option for emission control is through combustion process modification, flue gas treatment is needed for the control of sulfur emissions. Research in the Department has been conducted on the use of both disposable sorbents such as limestone for the capture of sulfur oxides and regenerable sorbents such as cerium oxide for the capture of sulfur oxides and zinc titanates for the capture of hydrogen sulfide. The combustion studies have provided, in addition to the processes for reduced emissions, interesting new observations on the formation of fullerenes (bucky balls), on reaction induced densification of chars, and on jet induced high speed coal particle rotation.

DEPARTMENTAL AWARDS

The Chemical Engineering Department's Awards Program was held on Wednesday, May 1, 1991, in the Edwin R. Gilliland Auditorium. Professor Brown, presided over the ceremonies at which the following awards were made.

The Dunbar Lancaster Shanklin Undergraduate Chemical Engineering Scholarships for 1990/91 to Rachel Huggins (junior, class of '92, from St. Louis, Missouri) and David C. Rich (junior, class of '92, from Plainview, New York) were acknowledged. The Dow Outstanding Junior Award recipient was Peter Ronco (junior, class of '92, from South Portland, Maine) for a balanced record of achievement in academic and campus professional and social organizations, as well as work experience.

The American Institute of Chemical Engineers 1990 scholarship to Kimberly Mislick (senior, class of '91, from Glastonbury, Connecticut) was acknowledged. This scholarship is awarded on the basis of a student's academic record, participation in AIChE activities and other civic and professional activities and future career plans. The American Institute of Chemical Engineers Annual Chapter Scholarship Award was given to George Alexopoulos (a junior, class of '92, from Athens, Greece), a member of the AIChE student chapter, for highest scholastic performance through the first two years in Chemical Engineering. The New England Chapter of the American Institute of Chemists (AIC) annually honors "outstanding seniors in recognition of potential advancement of the chemical professions on the basis of the student's demonstrated record of leadership, ability, character and scholastic achievement." This year's recipient was Joseph J. Berghammer (senior, class of '91, from Elm Grove, Wisconsin).

The Robert T. Haslam Cup was awarded to Alisa B. Mosler (senior, class of '91, from Kingwood, Texas) for outstanding professional promise in Chemical Engineering. The Roger deFriez Hunneman Prize, the oldest prize in the department begun in 1927, was given to Lisa Misterka (senior, class of '91, from Grafton, Massachusetts) in recognition of outstanding scholarship and research.

The newly initiated members of Tau Beta Pi, the Engineering Honorary Fraternity for excellence in academic studies, were acknowledged: Yvette Baxter (senior, class of '91, from St. Catherine, Jamaica), Alex V. Chachkes (senior, class of '91, from Phoenixville, Pennsylvania), Elizabeth J. Druding (senior, class of '91, from Painted Post, New York), George Alexopoulos, Joshua Levinson (junior, class of '92, from Endwell, New York), and David C. Rich; along with students previously inducted into Tau Beta Pi: Joseph Berghammer, Christine Gundal (senior, class of '91, from Centerville, Massachusetts), Elizabeth A. Jonsson (senior, class of '91, from Summit, New Jersey), Lisa Misterka, and Alisa Mosler.

The Dow Chemical Foundation Teaching Assistant Prize was awarded to Walter Lunsman (a graduate student, from San Antonio, Texas) for excellence in teaching in an undergraduate subject. Awards for second place were given to Deborah Savage (graduate student from West Columbia, South Carolina) and Tim Donahue (graduate student from Englewood, Colorado).

The Chemical Engineering Department Special Service Awards were given to Henry R. Holgate (graduate student of Malden, Massachusetts), Walter Lunsman, William G. Worley (graduate student from Morristown, New Jersey), Dawn Orton (graduate student from Mesa, Arizona), and Jean Condon (junior, class of '92, from Medford, Massachusetts) for their unselfish contributions to the success of departmental activities. The Chemical Engineering "Rock" Award for outstanding athletics, voted on by the graduate students in the department, went to Todd Salamon (graduate student from Bristol, Connecticut). The Department's Outstanding Employee Award was given to Carol Phillips, an Administrative Secretary, for exceptional service to the department and its students. The Chemical Engineering Outstanding Faculty Award (from the graduate students) was presented this year to Professor Daniel Blankschein. The Chemical Engineering Outstanding Faculty Award (from the undergraduate students) was presented to Dr. C. Michael Mohr.

ROBERT A. BROWN

Department of Civil Engineering

INTRODUCTION

One only has to read the daily newspaper or drive to work to see the problems that motivate research and education in the Department of Civil Engineering. Concern for the local, regional and global environment has reached a fever pitch. The over-crowding of transportation systems has caused congestion and lost opportunities that strongly influence our daily life. Infrastructure vital to the nation's economic health, productivity and public safety are in a serious state of disrepair. Our construction industry needs to become more productive, better managed and more technologically advanced to remain competitive. For over 130 years, the department has taken a leadership in the profession most aptly called "societies engineers." Working closely with the public we synthesize both structural and non-structural solutions for these demanding large scale and complex problems. This has led the department to invest in new evolving fields in education and research to increase our profession's ability to provide enlightened solutions. In the past several years, we have added extensively in important new areas to maintain and build our leadership. We have new specialists in the biology, chemistry and hydrologic aspects of local, regional and global environment. We are doing research in new materials and technologies for construction, in the assessment of the performance of existing facilities, in the use of computers for dramatically improving the design process, the construction process and the demanding interaction between them. Our students learn not only the technology of problem solving but also the important managerial skills to make them work and the societal context within which they will be best used. Society does not always speak with one voice nor is the natural and man-made environment always predictable with certainty. Thus our educational programs must prepare students to grow and evolve as more is learned and conditions change; to listen and communicate about the impacts of their projects, and to manage complex systems. We are having great success in all our programs. Our undergraduate numbers are well up, our graduate programs are well funded, robust and focused at important problems. Both are important models for the profession and our graduates continue to lead that profession. These are exciting times for us and we will continue to work at the forefront of knowledge as we always have. Specific activities of the department during AY 1990-91 follows.

Undergraduate Education

At the undergraduate level the department offers two main programs. One in which the the main focus is Course I-C Constructed Facilities and the other is Course I-E Environmental Engineering Science . We are working to improve and evolve both these programs and to handle the larger number of undergraduates we are attracting. A major issue is design and synthesis. Analysis is important and the skills needed for it, while difficult, are relatively well defined. However, how do we give our students a sense of problem solving; of thinking about imaginative and cost effective solutions sensitive to important safety, reliability and external constraints. We are integrating new design modules in our subjects to give the students a feeling for the problems of the profession and the way one thinks about innovative ways to approach those problems. We are participating extensively in the ESCEL design activities at the Institute as well as in our departmental activities, and we are doing research on computer aspects of design and visualization.

In the environmental area, we are now in the first year of our new designated Environmental Engineering Science Degree Program (the program had existed for four years as an experimental program before being voted into formal existence by the faculty in May 1990). Its aim is to provide a sound and fundamental understanding of physical, chemical, biological, economic and policy aspects of the field of environmental engineering. The program builds on the department's strengths in fluid mechanics, environmental chemistry, microbiology, ecology and hydrology, treatment technology and water resource systems. In addition, it allows a

student, with faculty guidance, to build programs over an interdisciplinary spectrum; drawing on the Departments of Chemical and Mechanical Engineering (sources and controls), Toxicology (human health effects), Urban Studies, Economics and Management (policy aspects). An important part of the program has been the formation of an interdisciplinary faculty Steering Committee to consider the content of the program.

The department also attracts students who are interested in engineering systems and computation and in the intersection between engineering and architecture. Special programs are developed by advisors for these students.

Graduate Program

The department has many vigorous research and educational programs at the graduate level. Its educational programs are organized about activities in three divisions: Constructed Facilities, Transportation Systems, and Water Resources and Environmental Engineering. Two additional programs which draw faculty cooperation between the divisions help to focus research and education on important specialized problem areas. These are the Center for Construction Research and Education which deals with the problems of the construction industry, and the Intelligent Engineering Systems Laboratory which deals with advanced aspects of computer-aided engineering.

Constructed Facilities Division (CFD)

The Constructed Facilities Division over the past year has focused on two major themes: "Condition Assessment of Existing Facilities" and "Improving Engineering Design." Research on condition assessment includes in-situ testing of soils, quantitative non-destructive evaluation of bridge decks and their supporting structure, and improved methods for processing images. An important contribution of the research team was the finding that conventional radar techniques for inspecting concrete bridge decks are grossly inadequate, and should be abandoned. Alternate techniques based on sonar and microwave technologies are under development, and the initial performance evaluations are quite promising. Research on "Improving Engineering Design" is concerned with a number of issues: i) establishing a rational theory and methodology for the design process, ii) using new advanced engineering materials in novel ways to obtain improved performance of structures and iii) developing a new generation of computer-aided engineering tools. CFD hosted a workshop in "Innovative Structures" at MIT in January 1991 which brought together key individuals from the construction materials, engineering design, and construction sectors in the United States, Europe and Japan. The division's research interest is focused on developing the engineering science base needed to use engineering materials such as fiber-reinforced cements in real world structures. A number of interesting developments in computer-aided engineering tools have occurred during the past year. Most of this work is carried out in the IESL, where divisional faculty play a key role, and is concerned with the design and prototyping of intelligent systems for engineering design, analysis, and knowledge acquisition. The interest in Design Theory and Methodology is being pursued in collaboration with faculty from the Mechanical Engineering Department, especially from Professor Nam Suh. Research in performance-based design has evolved beyond the conceptual phase, and is now poised for a major advance within civil engineering since it provides the basis for rational evaluation of the "quality" of a design.

In addition to the research activities, the academic programs have also been extensively modified to reflect the increased importance of condition assessment, design methodology, and computational engineering. A number of CFD faculty are participating in the ESCEL program, reflecting the division's commitment to improving the teaching of Engineering Design at the undergraduate level.

Transportation Systems Division (TSD)

TSD continues to work in the area of congestion, infrastructure, and logistics. Progress in these areas is reviewed as follows. The basic issue of modelling

steady-state congestion and long term intervention (e.g., new transit lines, ride sharing, etc.) has been mature (from a research point of view) for some time. Research activity has focused on technological solutions - intelligent vehicles, and intelligent guideways. Included here are all modes of transmitting congestion and routing information to drivers. To gauge the effectiveness of various schemes, faculty at the Division have been working on developing real time, dynamic traffic assignment methods, central control with partial compliance, driver "gaming," departure time management, and other models which would be required in the process of designing any system. Initiatives in a major new Intelligent Vehicle Highway System is now underway.

Logistics has continued to be a hot growth area of industrial activity and research. TSD has been active in adding new members to the CTS Affiliates and servicing existing members with visits, clinics, papers, and other communications.

Water Resources and Environmental Engineering Division (WREE)

Housed in the Ralph M. Parsons Laboratory (Building 48), this group is making a major contribution to environmental engineering and science research and education. It was the major impetus behind, and has the responsibility for the new designated degree program in Environmental Engineering Science. Together with the Graduate School they sponsored a one-day symposium on environmental graduate education at MIT, attended by interested faculty of the Institute. They continue to work with other departments within the Institute to enhance the subject offerings and content not only for designated degrees but also to enhance environmental literacy of all undergraduate and graduate students. Following the trend of the last 10 years, the research base of the group continues to grow, reaching close to \$5 million this fiscal year. Major research efforts involve the now well known Aberjona River Basin study of hazardous wastes in the Woburn MA areas. This collaborative study with the Center of Environmental Health Science assesses contamination of surface and groundwaters by toxic chemicals and resulting human exposure in a unique urban setting. Another continuing activity involves the evaluation of remediation alternatives for Boston Harbor. Work also continues on the properties of ocean waves and their remote sensing. New major experimental facilities, in development for some years, should be operational soon. Increasing research and educational efforts are being directed to the question of global environmental change, in particular the issues of hydroclimatology. Faculty in the division are now members of the science teams of the major NASA environmental missions. The Parsons Laboratory continues its tradition of cooperation and involvement with other groups throughout the Institute. Members of the faculty have major responsibility and leadership roles in the Hazardous Substances Group, Woods Hole Joint Program, Sea Grant, Energy Laboratory, Center of Environmental Health Sciences, and Center of Global Change Science. Professors Peter Eagleson and Rafael Bras now hold joint appointments in the Department of Earth, Atmospheric and Planetary Sciences.

The Parsons Laboratory was just awarded another \$500,000 for fellowships by the Parsons Foundation. This relationship is now in its fourth year. The initiative of the group also led to the selection of MIT as a participating university in DOE's Environmental Restoration Scholarship (for undergraduates in the new degree) and Fellowship (for graduate students) Programs. Two of our undergraduate students have already been selected to receive this type of awards. The Parsons Laboratory also was selected to receive \$700,000 from NSF for the renovation of facilities. An individual pledge, use of a grant from the Parsons Foundation, and MIT resources make up the bulk of the balance of the \$1,800,000 effort. The renovations touch every floor of Building 48 and will result in modern and expanded facilities that will serve MIT well for many years to come.

Intelligent Engineering Systems Laboratory (IESL)

The Intelligent Engineering Systems Laboratory is a research and academic group within the Department of Civil Engineering. The group focuses on the development and application of computer and communications technologies in engineering.

IESL's research program currently centers on three key areas: the collection, display and processing of visual information in engineering projects, tools that support engineering product development (particularly projects requiring interactions among large numbers of engineers), and real-time simulation of the operation of complex systems such as air traffic control and highways. The software development within the group relies heavily on object-oriented technologies, including programming languages and databases. Research in IESL is primarily funded through an industrial consortium in which the members share in the research results. Research plans are proposed by the faculty and reviewed by a joint academic/industry Advisory Board. This consortium currently funds \$1,150,000 per year of sponsored research that involves seven of the departments' faculty members and supports approximately 13 graduate research assistants. The research program in IESL links the department to the Media Laboratory, the Sloan School of Management, Draper Laboratory, the Operations Research Center and the Center for Transportation Studies.

Center for Construction Research and Education (CCRE)

In the nine years since its formation, CCRE has gained a reputation as a unique resource for development of new knowledge, and technical and analytical capabilities useful to the engineering and construction industry; and also for graduating a cadre of highly educated manpower to serve the industry. The stature of the center as an academic leader in the discipline of construction engineering and management, and as a focal point for significant and relevant construction research continues to grow. The Ph.D program is beginning to yield some exceptionally talented expertise in such areas as advanced construction materials, automation, robotics, information technology, and strategic management. This past year saw the completion of fifteen Masters and 6 Ph.D students. Another 9 students (6 Masters and 3 Ph.D's) are expected to complete their degrees by the end of this summer.

The center continues its success with large-scale research programs that support multiple projects throughout the department. The Army-sponsored Program for Advanced Construction Technology (PACT) is now in its fifth and final year. The experience gained, and track record established in the conduct of PACT research projects, initiated or enhanced the department's research focus in such areas as: automation and robotics; computer applications; remote sensing and condition assessment; virtual construction; technology evaluation; sources of innovation; geosynthetics in foundation engineering; advanced engineered materials (composites, ceramics and polymers); integration of design and construction; and infrastructure assessment and maintenance management.

This Spring the center established a new consortium on Construction and Global Environment; and signed a contract with Hazama Corporation which made this leading Japanese construction company a founding member of the consortium. The purpose of the consortium is to conduct research projects which lead to the identification of key areas and issues of global environmental change which are creating challenges and opportunities for the engineering and construction industry, and to the framing of effective strategies for meeting future environmental needs and markets. Eleven CCRE graduate students are currently involved in environmental awareness; current market opportunities and technological options; programs and technologies for hazardous waste site remediation; and surveys of owners, engineering design and consulting firms, construction contractors, and technology developers involved in the environment market. This environmental work was the theme of the Spring 1991 issue of the center's Newsletter CONSTRUCTION, and is helping to formulate a major element of the department's overall environmental agenda.

Department Administration

Department Head, Professor David H. Marks
Chairman of the Undergraduate Program, Professor Daniele Veneziano
Undergraduate Research Opportunity Program (UROP) Coordinator, Professor Harold Hemond
Independent Activities Period (IAP) Coordinator, Professor Eduardo Kausel
Chairman of the Graduate Program, Professor Ole Madsen
Admissions Officer, Professor Eduardo Kausel
Coordinator of the Student Chapter of ASCE, Professor Andrew Whittle
Coordinator, Chi-Epsilon, Civil Engineering Honorary Dr. Jack Germaine
Head, Water Resources and Environmental Engineering Division, Professor Rafael Bras
Head, Constructed Facilities Division, Professor Jerome Connor
Head, Transportation Systems Division, Professor Yosef Sheffi
Head, Center for Construction Research and Education, Professor Fred Moavenzadeh
Head, Intelligent Engineering Systems Laboratory, Professor Steven Lerman
Engineering Internship Program Coordinator, Professor Oral Buyukozturk
Director, Academic Programs Office, Mrs. Carol McIntire

Institute Service Roles

The department continues to play an important role in the leadership of the Institute. Faculty members serving in such roles are: Professor Daniel Roos, Director of the Center for Technology, Policy and Industrial Development; Professor Steven Lerman, Director of the Center for Educational Computing Initiatives; Professor Richard de Neufville, Chairman of the Technology and Policy Program; Professor Frank Perkins, Dean of the Graduate School; Professor Joseph Sussman, Director of the Center for Transportation Studies; Professor Sallie Chisholm, head of the MIT/Woods Hole Program; Professor Herbert Einstein, Head of the REMERGENCE Laboratory; Professor W. Kendall Melville, Head of the Joint MIT/Woods Hole Program in Ocean Engineering; Professor Philip Gschwend, Head of the Joint MIT/Woods Hole Program in Chemical Oceanography; and Professor Rafael Bras, Associate Director of the Center for Global Environment.

Faculty and Staff Changes

Two new faculty started this year: Assistant Professor Lee Krumholz in the Water Resources and Environmental Engineering Division. Professor Krumholz is an environmental microbiologist and will work in the area of environmental bio remediation. Associate Professor John Williams is an expert in non-continuum mechanics and in the use of computers for visualization of the design and construction process. Professor Donald R. F. Harleman, Ford Professor of Engineering, retired in January 1991 but continues to teach and do research in the Water Resources and Environmental Engineering Division. Five Professors were on leave: Professor Lorna Gibson, Professor Keith Stolzenbach, Professor Oral Buyukozturk, Professor Charles Ladd, and Professor Sallie Chisholm.

Promotions

To Associate Professor with tenure, Professor Dennis McLaughlin
To Professor, Professor Harold F. Hemond
To Senior Research Engineer, Mr. Carl Martland

Department Statistics

Number of Faculty: 38, June 1991. Number of Undergraduates: 130; Number of Graduate students: 254; department research expenditures for AY 90-91: \$7.5 million.

Faculty and Staff

Dr. E. Eric Adams, Principal Research Engineer (WREED), continues his research on Boston Harbor. Fluorescent tracer studies, mathematical modeling and analysis of sediment cores suggest that the impact of Combined Sewer Overflows (CSOs) discharged to inner harbor regions such as Fort Point Channel is mainly on the inner Harbor itself, and not on outer Harbor beaches. Combined with growing evidence that actual CSO loadings are less than previously thought, this new evidence suggests a possible downsizing of the billion dollar CSO tunnel project

proposed as part of the CSO Facilities Plan. He is also involved in the development of a new 3-D model for coastal pollutant transport and supervised an undergraduate IAP field study of the impact of future Charles River bridge crossings (e.g., Scheme Z) on operation of the Charles River Pump Station. He organized the International Conference on Physical Modeling of Transport and Dispersion, held at MIT in August, and is Chairman of ASCE's Hydraulics Division Awards Committee.

Professor Moshe Ben-Akiva (TSD) has initiated a major research program "Cooperative Research Program on Intelligent Vehicle-Highway Systems" (IVHS) for which he will serve as Program Director. This program involves faculty from the Civil Engineering Department's Intelligent Engineering Systems Laboratory (IESL), the Center for Transportation Studies (CTS), the Center for Technology, Policy and Industrial Development (CTPID), Lincoln Laboratory, and the Mechanical Engineering Department's Man-Machine Systems Laboratory. In addition Prof. Ben-Akiva was recently awarded an International Energy Policy Research Grant by the Japan Endowment Fund for his project "Assessing the Potential Impact of Telecommunications Options on Travel Reductions" and is continuing his participation in the MIT Telecommunications Business and Economics Program.

Professor David Bernstein (TSD) is currently doing most of his research on the impacts of urban and suburban congestion and demand-oriented strategies (e.g., road pricing, high-occupancy-vehicle facilities, parking policies, growth management) for alleviating the problems it causes. In particular, he is both developing models that can be used to predict the value of various strategies and working on making these models accessible to decision makers. To that end he developed a new course in the Spring of 1991 entitled Geographic Information Systems for Transportation Planners and Engineers.

Professor Rafael Bras (WREED) after eight years on the job, will step down as Director of the Ralph M. Parsons Laboratory August 30, 1991. He will continue as Associate Director of the Center for Global Change Science. He now holds a joint appointment in the Department of Earth, Atmospheric and Planetary Sciences. Professional service during the past year include Chairmanship of the Budget and Finance Committee, American Geophysical Union; Advisory Board of the Engineering Directorate, NSF; Board of Atmospheric Sciences and Climate, NRC; Advisory Panel, NSF's Continental Hydrology Program; Advisory Subcommittee of the Earth Sciences and Applications Division, NASA; and the Science Panel of GEWEX' Continental Scale International Project. Prof. Bras was also recently selected to the Science Team of NASA's Tropical Rainfall Measuring Mission. Besides many journal publications, Prof. Bras also published a solutions manual to his most recent textbook, *Hydrology: An Introduction to Hydrologic Science*.

Professor Oral Buyukozturk (CFD) developed three new research directions. The first is on the development of high performance concrete (strength, ductility, durability) which involves investigation of interface behavior between the cement matrix and inclusions. The second is on the nondestructive evaluation of concrete using microwave techniques, jointly conducted with the Department of EECS and Lincoln Laboratory. Two joint proposals on this topic were developed. The third research area is on the prediction of fatigue life of railroad bridges and their repair. He inspected deteriorated bridges in the Richmond, Virginia area for CSX; an effort which led to the development of a new research proposal to CSX. During April and May 1991 as part of his sabbatical leave he gave a series of lectures at Swiss Federal Institute of Technology (ETH), Technical University of Berlin, and Milan Polytechnic Institute.

Professor Sallie W. Chisholm (WREED) while on sabbatical leave organized and ran a special symposium "What Controls Phytoplankton Production in Nutrient-Rich Areas of the Open Sea" for the American Society of Limnology and Oceanography to explore the scientific issues underlying the proposal that iron fertilization of the Antarctic oceans might significantly reduce CO-2 accumulation in the atmosphere

and ward off greenhouse warning. She is now editing with Prof. Francois Morel a special issue of Limnology and Oceanography including the proceedings of the symposium. This will be out by the end of the year and will be the "authority" on the subject.

Professor Peter Eagleson's (WREED) intensive three-year effort as Chairman of a National Research Council committee culminated in February with the publishing, by the National Academy Press, of the report "Opportunities in the Hydrologic Sciences." The report's recommendations are expected to generate the missing research and educational infrastructure for hydrologic science, a geoscience that has been identified by OSTP as having top priority in the U.S. Global Change Research Program.

Professor Herbert Einstein (CFD) continues to be called upon for advice on three of the world's major tunneling projects; namely, the Central Artery Third Harbor Tunnel in Boston and the Transalpine Tunnels in Switzerland and Austria/Italy. His work on the multimedia Geology Tutor for Project Athena continues.

Professor Ralph Gakenheimer, Urban Studies and Planning, joint appointment with Civil Engineering, is working on research to determine ways of rebuilding the residential structure and infrastructure of the city of Beirut following the hostilities in Lebanon. He has recently finished a project on suburban congestion in the Boston area, the last in a series of several contracts. This one involved roles of the environmental impact review in suburban congestion alleviation. During last year he finished a general report of a UNHABITAT expert group meeting on the choice of modes for public transportation in large cities of the developing world. He did the Keynote Address on Transport for Megacities, a conference sponsored in May by the World Bank.

Professor Lynn Gelhar (WREED) is putting the finishing touches on an important new book entitled "Stochastic Subsurface Hydrology which is scheduled for release in 1991. His research focusing on field-scale contaminant transport in groundwater includes a new initiative characterizing the aquifer conditions in the area of a subsurface contamination plume encompassing a 30km on Cape Cod. He is also involved in a large cooperative project looking into groundwater contamination in the Aberjona River Watershed just north of Boston. Also, his group has developed a large-scale three-dimensional supercomputer simulations of the biodegradation of contaminants in groundwater.

Dr. John T. Germaine (CFD) has continued participation in ASTM standards writing, which is a very effective mechanism for knowledge transfer to the profession. He continues in his effective running of the Geotechnical Laboratory and is Advisor/Den-Mother for the ASCE concrete canoe race. His research interests are focused on the use of computer automation to measure material properties with sufficient precision to investigate the mechanisms which control behavior. Current projects are looking at cyclic behavior, strain rate effects, frozen properties and soil reinforcement. My automation techniques have allowed our graduate students to perform tests with unprecedented productivity and quality. The next five years hold enormous potential for major advances in basic understanding of soil behavior.

Professor Lorna Gibson (CFD) spent the 1990-91 Academic Year on sabbatical at the Division of Applied Sciences at Harvard University in the Applied Mechanics Group. She collaborated with the faculty there on two new problems. The first is the analysis of the mechanical behavior of composite cellular solids, for instance, composites of hollow spheres of one material in a matrix of another. The second is measuring and modelling the compressive fatigue behavior of cancellous bone. Both projects are now established and progressing well. She hopes to continue both collaborations in the future. At the end of the academic year she learned that she was on the list of finalists for the National Science Foundation Faculty Awards for Women Scientists and Engineers.

Professor Donald R. F. Harleman (WREED) is supervising full plant tests of chemically enhanced primary treatment at the Salem plant of the South Essex Sewerage District. Both alum and ferric chloride and a number of polymers are being used to increase treatment efficiency of this conventional wastewater plant. Three months of data, using varying concentrations of chemical additives, will be obtained. The information will be used to reduce the size and cost of secondary treatment facilities needed to bring the treatment plant into compliance with the state and federal regulations. Aerated biofilters, an innovative and cost-effective form of secondary treatment, are proposed.

Professor Harry Hemond (WREED) continued work with co-author Elizabeth Fechner, on new text entitled "Fate and Transport of Chemicals in the Environment." Several publishers have verbally indicated intent to offer contracts, and McGraw-Hill has recently forwarded a signed contract. He constructed microcomputer interface for backpack-portable mass spectrometer and began software development. He has continued research on trace gas emissions from northern peatlands, proposing a new technique for measuring net methane evolution and oxidation without disturbing the peatland surface and thereby creating artifacts.

Mr. Thomas F. Humphrey (CTS) is the Director of the Region One (New England) University Transportation Center located at MIT. This federally funded program provides \$1 million annually to MIT, which must be matched equally with non-federal funds. The third year program, covering September 1, 1990 - December 31, 1991, provided four fellowships for MST candidates. The research program sponsored by the Region One UTC is focused on IVHS, Transit and Public Policy issues. US DOT rated MIT's program in the top three of the ten centers established nationally. MIT formed a consortium of the six New England State universities together with the JFK School of Government at Harvard University to carry out this regional program.

Professor Eduardo Kausel (CFD) serves this year as Chairman of ASCE's Dynamics Committee. He has made good progress in research in Condition Assessment and in Structural Acoustics. He presented a paper at the second Panamerican Congress of Applied Mechanics. Prof. Kausel was Chairman and Reporter for a session at the International Conference on Soil Dynamics and Earthquake Engineering, and he presented an invited lecture on Soil-Structure Interaction at the University of Coimbra in Portugal.

Professor Haris Koutsopoulos (TSD) continued his research activities during the past year in the areas of automated analysis of pavement data and Advanced Driver Information Systems (ADIS). Jointly with Prof. Ben-Akiva he initiated two new projects in ADIS and with Profs. Ben-Akiva and Logcher a new project in IVHS. He made several presentations on these topics. He also presented a tutorial on "Strategies on Parallel Computing" at the Transportation Research Board's Annual meeting.

Professor Lee Krumholz (WREED) joined the faculty in January 1991 after completing a Postdoctoral research program at Stanford University. He is involved in studying bacterially mediated processes in the environment. Currently, his research is focusing on microbial degradation of hazardous organic solvents which have made their way into ground and surface waters. The goal of these studies is an improved understanding of the degradation of these compounds with the intent to improve bioremediation technology. He is also beginning a research project in collaboration with Prof. Hemond on the microbiology of methane release from northern peatlands. Peatlands are thought to be important sources of methane (a greenhouse gas). He will be teaching environmental microbiology in the fall and a graduate course in environmental microbial processes during the spring semester.

Professor Steven Lerman (TSD) directs the Civil Engineering Department's Intelligent Engineering Systems Laboratory (IESL). His research within this lab focused on massively parallel algorithms for sparse network analysis. This year

he chaired the Advisory Committee on the Search for the Dean of Engineering. In March Prof. Lerman was appointed Director of the new Center for Educational Computing Initiatives. This Institute-wide Center will carry forward MIT's leadership in educational computing started with Project Athena. He was awarded the Class of 1922 Professorship.

Professor Robert Logcher (CFD) presented a week long symposium on Project Control at the Universidad Gabriela Mistral in Santiago, Chile and was on the organizing committee for the Research Needs Forum organized by the Civil Engineering Research Foundation. Along with Professor Duvvuru Sriram he organized a short course on Object Oriented Systems and continued research and presented work on using such systems for design coordination and design for constructibility at several conferences. He continues as Co-Technical Director of IESL, with additional research in real time systems for air traffic control, intelligent project planning systems, and deployable structures.

Professor Ole S. Madsen (WREED) during the period of 1 July 1990 to 30 June 1991 obtained funding for three new research projects concerned with sediment transport processes in the marine environment. One, supported by Sea Grant, is a laboratory study, another sponsored by NSF is a joint project with Virginia Institute of Marine Science involving field investigations, and the last, with support from Office of Naval Research, is concerned with the development of improved theoretical models. He taught a freshman advisor seminar during the fall on "The Fluid Environment" to ten freshman advisees in addition to his usual graduate subject.

Mr. Carl Martland, Senior Research Associate, (TSD) for the second straight year shared the \$1500 Conrail Award for the best paper on railroads presented to the Transportation Research Forum. He also presented a paper to the International Heavy Haul Conference in Vancouver. In addition to continuing several projects on railroad track maintenance planning, Mr. Martland is the principal investigator for a major new research project on railroad reliability that is sponsored by the Association of American Railroads.

Professor Dennis McLaughlin (WREED) continued to develop new techniques for characterizing and predicting groundwater contamination. He has also been using his research experience to develop some innovative new computer-oriented educational tools. He recently joined Prof. Adel Sarofim of Chemical Engineering and Dr. John Ehrenfeld of the Center for Technology, Policy and Industrial Development in a team effort to give Chemical Engineering undergraduates in 10.362 an opportunity to design a realistic groundwater remediation program. As part of this effort Prof. McLaughlin and Tim Wall, an undergraduate Electrical Engineering student, wrote an interactive computer package which simulates the various stages of a hazardous waste cleanup on readily available Project ATHENA workstations. Plans are to use the package in a number of other courses, including the award-winning Chemicals in the Environment series. In April 1991 Prof. McLaughlin and Dean Frank Perkins jointly organized a Faculty Colloquium on Graduate Environmental Education at MIT. This colloquium helped stimulate interaction among faculty involved with environmental studies.

Professor Chiang C. Mei (WREED) delivered a paper at the Fourth International Conference on Land Subsidence in Houston and has accepted an invitation to give one of five Keynote talks at the Second National Congress of Fluid Mechanics in Los Angeles in 1992. He has accepted an invitation to write a review article on coastal hydrodynamics for Annual Review of Fluid Mechanics 1992. He is also writing a section on coastal hydrodynamics for the "Subcommittee on Research Direction in Fluid Mechanics," to be submitted to the National Research Council in 1992.

Professor Fred Moavenzadeh Director of the Center for Construction Research and Education was asked to speak at several seminars, workshops, and meetings on various construction-related topics, including the following: the Civil Engineering Research Foundation Symposium on Construction held in Washington; the Construction and Engineering meeting of the World Economic Forum in Davos, Switzerland; the Global Infrastructure Research Foundation meeting in Tokyo, Japan; the American Road and Transportation Builders Association in Washington, DC on Privatization and What is in it for Contractors;" the United Nations Centre for Human Settlements and the American Chemical Society. He has put together a Consortium on Global Environment and the Construction Industry which is being sponsored by the Hazama Corporation of Japan and he is heading a collaborative research effort with the American University of Beirut on the "Reconstruction of Lebanon," which is being funded by the Hariri Foundation.

Professor Francois Morel's (WREED) teaching activities during 1990-91 have included his Aquatic Chemistry course in the Fall and a new course on Trace Element Ecotoxicology in the Spring. He has been revising his teaching text "Principles of Aquatic Chemistry" whose new addition is due to appear at the end of 1991. Among his many invited talks and seminars, he gave a series of lectures at the Ecole Normale Superieure in Paris on the Chemistry of Trace Elements in Natural Waters. His present research activities are aimed at determining the role of trace elements in oceanic primary productivity at developing a thermodynamic model of humic acid chemistry, and at quantifying the biological effect of metal pollution.

Professor Daniel Roos (CTPID) was co-author of The Machine That Changed the World, a book that summarizes the principle conclusions of the International Motor Vehicle Program. The book was selected as the best business book of the year by the Financial Times and has been translated into seven languages. Professor Roos obtained a grant of \$2 million from the Alfred P. Sloan Foundation to continue the work of the International Motor Vehicle Program for an additional three year period. Professor Roos is the Chairman of the National Research Council Committee for the Study to Assess Advanced Vehicle and Highway Technologies, and a member of the National Research Council Committee on Fuel Economy of Automobiles and Light Trucks. Professor Roos was appointed to the Executive Committee of IVHS America, a new organization to coordinate the development of intelligent vehicle highway systems.

Dr. S. Shyam-Sunder (CFD) continues his research in the field of ice mechanics. This research is concerned with the development of physically-based constitutive theories for the deformation and progressive fracture of ice, finite element analysis of ice-structure interaction, and the molecular dynamics of icing on cable and structures. He presented one of the Keynote talks at an ONR Workshop on Sea Ice Mechanics and was invited to talk at the US National Academy of Sciences - Academy of Sciences of the USSR Workshop on Ice Mechanics in Moscow. A professional thrust in the area of engineering design was initiated during the year. The NSF sponsored ECSEL Program funded a Design Laboratory that seeks to broaden the Civil Engineering curriculum. Professor Duvvuru Sriram (CFD) is teaching the undergraduate course entitled Engineering Applications of Artificial Intelligence and a very successful summer course on Object Oriented Systems (with 42 participants from industry). He has been selected to give the Artificial Intelligence in Engineering Design tutorial at the American Association of Artificial Intelligence 1991 Annual meeting (around 5000 people attend this conference). His work on integrated design has been presented (with Prof. Logcher) at the Seventh ASCE Conference on Computing in Civil Engineering, Washington, D.C.; Building Systems Integration Symposium, University of Wisconsin-Madison; and New Jersey Institute of Technology.

Professor William G. Thilly, Toxicology, holds a secondary appointment in Civil Engineering where he works with our environmental group. His work with us involves the coordination of MIT-wide research efforts which include the Aberjona Basin Study of the movement and human health effects of chemicals from the Superfund Sites.

Professor Thanasis Triantafillou (CFD) has developed two new subjects: Design of Structures at the undergraduate level and Innovative Structural Technologies at the graduate level. His main research interest is in the application of advanced composite materials in combination with traditional materials to maximize structural performance. He is conducting research for the Army in the use of composites as external reinforcement of concrete and wood structures, in applications involving rehabilitation and new constructions. In collaboration with the Swiss Federal Laboratories for Materials Research, Prof. Triantafillou is developing new concepts for the combination of composites with concrete to produce high efficiency members. He is also involved in a research project on low-cost innovative designs of MAGLEV Transportation.

Professor Robert Whitman (CFD) as part of MIT's effort in the NSF-funded ECSEL Program has taken on a leadership role in the introduction of engineering design as a first-year subject and in the curriculum of civil engineering. In research, he has continued to participate in an eight-university study of earthquake-caused liquefaction, based upon geotechnical centrifuge tests. In January, he was asked to join an Advisory Board reporting to the Director of the Federal Emergency Management Agency to guide the National Earthquake Hazard Reduction Program.

Professor Andrew Whittle (CFD) continued research work on five projects and supervised six Ph.D. students throughout the year. His activities have included the publication of a major report on the interpretation of in situ tests in clays, the first measurements of load-transfer interaction in geosynthetic reinforcement cell, and the development of a new analytical framework for predicting soil deformations due to deep excavations in clays. A journal paper on his constitutive model for clays has been accepted for publication in *Geotechnique*. He has been invited to present a state-of-the-art paper on the analysis of driven piles in clays at a major conference on Offshore Site Investigation and Foundation Behaviour in London next year.

Professor John R. Williams' (CFD) book entitled *Numerical Modeling in Rock Mechanics*, co-authored with Gyan Pande and Gernot Beer, was published by John Wiley and Sons. The book details the basic theory of the Discrete Element Method along with the more traditional Finite Element and Boundary Element approaches. The graduate course 1.551 Computer Aided Engineering was revised to teach software design based on a top down design framework. The major group project successfully involved the design and development of autonomous software robots which live (and die) in a real-time virtual world.

Professor Nigel H. M. Wilson (TSD) taught a one-week course at MacQuarie University in Sydney, Australia in July on Public Transportation Service and Operations Planning attended by thirty-six professionals from Australia and New Zealand. He entered into a contract with Prentice Hall jointly with Professor Steven Lerman to write a text for Subject 1.00 Introduction to Computers and Engineering Problem Solving. He presented seminars at the University of Pennsylvania on Improved Workforce Planning and management in the Transit Industry and at the Energy Lab at MIT on Energy and Public Transportation as part of an IAP seminar series. He Co-chaired the Transportation Research Board's Summer Meeting on Public Transportation held in August in Ann Arbor. He continues to serve as Associate Editor for *Transportation Science* and as a member of the Editorial Advisory Board for *Transportation Research Part B* and the *UITP Revue*.

Department of Electrical Engineering and Computer Science

This year the department continued its investigation of a new professional curriculum for both electrical engineering and computer science. The current thinking is that five years is necessary for a professional engineer, but that an education suitable to prepare a person for a career outside of engineering but still heavily based on science and technology can be done in four years. Some students may still prefer to take a professionally-directed four-year program and that may be possible, but clearly less desirable than the integrated five-year program. The principal obstacle to implementing such a change is the costs associated with developing the new curriculum and with supporting the instruction in the fifth year.

Undergraduate enrollment in the department is expected to rise next year. In Fall 1990 the number of sophomores who selected electrical engineering or computer science majors was more than 20% larger than for the previous year (which itself was up ten percent from the year before that). If this trend continues, we may be faced with the problem of coping with high enrollment, just as we were during the mid 1980s.

Progress has been made on the definition of an ambitious research program in telecommunications for the 21st century. The national (and worldwide) infrastructure for data communications, video communications, and voice will require definition and development, based on available technology, applications, and regulatory/legal issues. Thus a very broad-based, interdisciplinary research activity is necessary. It is felt that MIT can play an important role in designing what the nation needs. In his inaugural address, President Vest announced the formation of this "information infrastructure initiative."

UNDERGRADUATE PROGRAM

Enrollment of undergraduates averaged 950 in 1990-91, with about 60 percent in the Electrical Engineering Program and 40 percent in the Computer Science Program. From the Class of 1993, 350 students enrolled in Course VI, which was a substantial jump from the approximately 275 students we had been receiving from each class. Our concerns that this trend might continue with the Class of 1994 appear to have been unfounded, as we seem to have returned to about 275 students. Interestingly, the ratio of 6-1 (Electrical Engineering) to 6-3 (Computer Science) students seems to have altered radically, from 2:1 to almost 1:1. This means that the Class of 1994 has the largest number of Computer Science students in the department's history, with approximately 140 students.

The following prizes and awards were won by our students:

The Ernst A. Guillemin Prizes for the outstanding S.B. theses in Electrical Engineering were awarded to Michael Rizen of Huntington Valley, PA (First Prize), and to Su-Lin Low of Singapore (Second Prize). Honorable Mentions went to Andrew P. Alleman of Brookline, MA, Patrick C. Chou of Ann Arbor, MI, Flora S. Tsai of Taiwan, and Regan Mills of North Anson, ME.

The David Adler Memorial Thesis Prizes for Undergraduate Theses in Electrical Engineering were presented to Joel R. Phillips of Ranchester, WY (First Prize), and to Kevin Klughart of Richardson, TX (Second Prize).

The Charles and Jennifer Johnson Prize for the outstanding undergraduate thesis in Computer Science was presented to Elmer Hung of Huntsville, AL.

The William A. Martin Memorial Prize for the best thesis in Computer Science was won by David Bruce Wilson of O'Fallon, IL.

The Computer Systems Prize was not awarded this year.

The George C. Newton Prize for the best undergraduate laboratory project was awarded to Stan Y. Liao of Rancho Palos, V., CA, and to Michael de la Maza of Irvine, CA.

The David A. Chanen Writing Award for the best Computer Science paper used to satisfy the second phase of the Writing Requirement went to Hong-Kwang Jeff Kuo of Flushing, NY.

Two Special Recognition Awards were presented by the Department Head to Omer Uzun of Atlanta, GA, and to Derek T. Mayweather of Stone Mountain, GA.

GRADUATE PROGRAM

In September, 1990, there were 670 graduate students enrolled in the department. Of this number 192 were newly admitted. About 20 percent of the total were foreign nationals. The department supported 310 Research Assistants, 105 Teaching Assistants. In addition, there were 146 fellowships including 37 National Science Foundation Fellows, 6 Hertz Fellows and 17 ONR Fellows. The remaining students had industrial or foreign support or were using their own funds.

During 1990, the department awarded 170 Master of Science degrees, 13 Electrical Engineer degrees, and 61 doctoral degrees.

The department received 1727 applications for the 1990-91 year, a slight increase over 1989. The applications continue to be generally excellent and 286 students were admitted for 1991 (February, June, and September) of whom approximately 115 are expected to register for next fall.

A number of awards were made to graduate students for excellence in teaching. John R. Buck of Rochester, NY, received the Carlton E. Tucker Award and Andrew C. Singer of Hoffman Estates, IL, received the Harold L. Hazen Award. The Frederick C. Hennie III awards for excellence in teaching were presented to Victor S. Liau of Acton, MA, and Henry Stavisky of Miami Beach, FL. Gregory W. Wornell of Maple Ridge, BC, Canada, was the recipient of the Goodwin Medal. Andrew E. Ayers and Tracy M. Clark were promoted to Instructor G in recognition of their demonstrated teaching abilities and services to the Department.

VI-A INTERNSHIP PROGRAM

In its 73rd year, the Department's VI-A Internship Program continued its popularity and excellent performance. During this year's selection process the number of sophomores who applied was 197, an increase of 40 over the previous year. This is perhaps due to the larger size of the sophomore class, coupled with the desire of the students to have meaningful employment in the sluggish economy. Because of the business climate, the participating companies were more cautious in making offers. As a result, only 77 students were made offers. This made the selection opportunity somewhat lower than anticipated.

Although company participation remained stable with no new companies added this year, it is apparent that a careful look at the possibility of adding some new companies this coming year will be necessary. In June, 38 VI-A students received advanced degrees having completed all the company assignments and Institute degree requirements. There were 24 students who were awarded their Bachelor's degrees and most of them will continue into the graduate phase of the Program.

At the Institute Awards Convocation and at the annual Department Social and Awards ceremony in May the following students were honored. John R. Buck received the Carlton E. Tucker Award for excellence in teaching; Victor S. Liau and Henry Stavisky were recipients of the Frederick C. Hennie III Award; Hong-Kwang Kuo, the David A. Chanen Writing Award for outstanding performance on the Institute Writing Requirement in the area of computer science; Sourabh A. Niyogi, the Robert M. Fano UROP Award for outstanding performance on a UROP project in the department; Christopher A. Cooke, Todd E. Knibbe, and Karl Sun, the Bell-Northern Research, Inc. Project Award; Heather E. Walters, Special Recognition Award for meritorious service to the department; Anthony Jules won First Prize in the poetry division by the Writing Program; Brian L. Lawrence, Honorable Mention of a Boit Writing

Prize; Ganesh N. Ramaswamy, First Prize in the Writing Program for Engineering Writing; Firdhaus Bhathena, Honorable Mention in the Writing Program for Engineering Writing; Pankaj Oberoi, Pettegrove Award in recognition of outstanding service to intramural activities; and James H. Bandy, men's swimming, All-America 800-yard freestyle relay.

VI-A students continue to excel in their studies as attested by Michael M. Goodwin being the recipient of the Henry Ford II Scholar Award; Gregory K. Toth, the 1991 Bose Foundation Fellowship; and Sanjeev Agrawal received one of 35 Tau Beta Pi graduate fellowships given to students nationwide.

The following students were elected to the Xi Chapter of Phi Beta Kappa: Sanjeev Agrawal, Lars E. Bader, Vijay Balasubramanian, Hong-Kwang Kuo, David S. Miller, Sae Woo Nam, and Dinesh R. Tummala.

MICROSYSTEMS TECHNOLOGY LABORATORIES (Professor L. Rafael Reif)

The Microsystems Technology Laboratories (MTL) carry out research in the fabrication and study of small monolithic structures and their use for the implementation of interesting integrated systems from X-ray lenses to VLSI circuits. The expanding and dynamic research program covers solid state devices, integrated circuits, materials for electronic applications, novel process technologies, sensors and actuators, and computer-aided fabrication. The MTL includes three clean room facilities (the Integrated Circuits Laboratory, the Technology Research Laboratory, and the Submicron Structures Laboratory), an associated non-clean laboratory space (the Research Group Laboratories), and the Computational and Communication Network facility. The centerpiece facility of the MTL is the Integrated Circuits Laboratory, a state-of-the-art class-10 clean laboratory with full capabilities for modern IC fabrication. The laboratory is operated by full time technical staff and graduate students.

The research dollar volume in FY91 was approximately \$8.49 million. The people involved include 18 faculty, four senior research staff, 130 graduate students, 32 undergraduate students, 22 technical support staff, and 11 administrative and support staff. These faculty and personnel represent affiliations including the Departments of Electrical Engineering and Computer Science, Materials Science and Engineering, Chemical Engineering, Mechanical Engineering, Brain and Cognitive Sciences, Civil Engineering and Physics; the Center for Materials Science and Engineering, the Research Laboratory of Electronics, the Laboratory for Electromagnetic and Electronic Systems, the Laboratory for Information and Decision Systems, the Laboratory for Computer Science, the Center for Space Research, and the Turbulence Research Laboratory. During the 1990-91 academic year, 26 Ph.D. and 21 S.M. degrees were awarded in conjunction with this research.

Research in MTL may be grouped into eleven categories:

- (1) **Integrated Circuits** include analog and digital integrated circuit (IC) design as well as advanced process development for "mixed analog/digital signal" IC applications.
- (2) **Integrated Sensors** include technologies for micromachining, design of microsensors and microactuators, and the application of these devices to physical and chemical measurements.
- (3) **Power Devices and Circuits** include research in very high frequency power converters, power device performance, and novel fabrication procedures for energy storage devices.
- (4) **Electronic Devices** include research on novel devices operating in the semi-classical regime.
- (5) **Quantum Effect Electronics** include novel device structures designed specifically to study and explore quantum mechanical effects arising from carrier interactions with features of sub-100 nm dimensions.

- (6) **Submicron and Nanometer Structures** include some "nanofabrication" projects that are not directly related to electronic devices. The Submicron Structures Laboratory develops techniques for the fabrication of surface structures with feature sizes in the range of nanometers to micrometers, and uses these structures in a variety of research projects.
- (7) **Process and Device Modeling and Simulation**, an actively developing area, uses numerical techniques that solve complex problems of carrier transport and device operations as well as physical problems that arise during materials and device processing.
- (8) **Fabrication Technology** covers a broad area of processing and device fabrication with two main themes: novel processes for integrated circuit and device fabrication in silicon and compound semiconductors, and fundamentals underlying materials processing effects.
- (9) **Computer-Aided Fabrication** includes computer-based modeling and simulation of fabrication processes and execution in a realistic fabrication environment; work flow scheduling; process equipment modeling and process control; and microstructure/mechanical property simulation.
- (10) **Materials**, with the common theme of growth and characterization of thin films for electronic application, include research of novel silicon epitaxy, the formation of heterostructures in compound semiconductors, polyimides in microelectronics, and the study and control of the crystalline structure of very thin films.
- (11) **Packaging** includes advanced chip assembly and study of passivating properties of different materials in thin film form.

The MTL facilities are supported in part by members of the MIT Microsystems Industrial Group, whose current members include: Analog Devices, Inc.; AT&T; Digital Equipment Corporation; Draper Laboratories; General Motors Corporation; Hewlett-Packard Company; IBM; Intel Corporation; Motorola, Inc.; Polaroid Corporation; Raytheon Company and Texas Instruments.

Coordination activities carried out by MTL include a weekly VLSI seminar series, a unified VLSI Memo Series, and an annual Microsystems Research Review. The MTL publishes an annual report entitled *Research in Microsystems Technology*.

FACULTY

The department welcomed James E. Chung and Lynn A. Stein to the faculty this year. Chung received his Ph.D. at the University of California, Berkeley and is now Assistant Professor of Electrical Engineering. Stein received her Ph.D. at Brown University and joined us as Assistant Professor of Computer Science.

Associate Professors Harold Abelson, Pierre A. Humblet, Jeffrey H. Lang, Tomás Lozano-Pérez, and Silvio Micali were promoted to Professor. Assistant Professors Munther A. Dahleh, Jesús A. del Alamo and Jacob K. White were promoted to Associate Professor.

Faculty members received many honors and awards this year:

Professor Arthur B. Baggeroer was named Ford Professor of Engineering.

Professor Amar G. Bose received an honorary Sc.D. from Framingham State College.

The International Joint Conference on Artificial Intelligence honored Associate Professor Rodney A. Brooks with its Computers and Thought Award.

Professor Fernando J. Corbató the A.M. Turing Award, the Association of Computing Machinery's (ACM) most prestigious honor. The Turing Award is given for contributions of lasting and major importance to the computing field. Professor Corbató was cited for his pioneering work in the development of the general-purpose, large scale, time-sharing and resource-sharing computer systems, CTSS and Multics.

Professors Randall Davis, Berthold K.P. Horn, Tomás Lozano-Pérez, Marvin L. Minsky, Marc H. Raibert, Gerald J. Sussman, Patrick H. Winston, and Associate Professor Rodney A. Brooks were elected Founding Fellows of the American Association of Artificial Intelligence.

Associate Professor Jesús A. del Alamo was named ITT Career Development Associate Professor of Electrical Engineering.

National Science Foundation Presidential Young Investigator Awards went to Associate Professor Jesús A. del Alamo and Assistant Professors Anant Agarwal, Munther A. Dahleh, Martha L. Gray, and Martin A. Schmidt.

Professor Alvin W. Drake was honored with the Amar Bose Teaching Award in recognition of his outstanding contributions to undergraduate education.

Associate Professor Peter L. Hagelstein received the American Physical Society Award for Excellence in Plasma Research.

The prestigious IEEE Education Medal was awarded to Institute Professor Hermann A. Haus for excellence and leadership in teaching, writing and research. He also received an honorary doctorate from Technical University of Vienna.

Professors Berthold K.P. Horn and John L. Wyatt, Jr. were this year's Adler Scholars. The Adler Scholar program enables faculty members to take time off from teaching and instead take a class as a regular student. Professor Horn took 6.775 Design of Analog MOS LSI and Professor Wyatt took 6.866 Machine Vision.

Adjunct Professor Robert H. Kingston was elected to the National Academy of Engineering.

Associate Professor James L. Kirtley, Jr. was elected a Fellow of the IEEE.

Professor Roger G. Mark was named Grover Hermann Professor in Health Sciences and Technology.

Professor Albert R. Meyer was named Hitachi America Professor of Computer Science and Engineering.

Professor Silvio Micali was named Cecil H. Green Professor of Computer Science and Engineering.

Professor Marvin L. Minsky received the Research Excellence Award from the International Joint Conference on Artificial Intelligence.

Professor Joel Moses was appointed Dean of the School of Engineering.

Professor Alan V. Oppenheim was named Distinguished Professor of Electrical Engineering.

Professor Ronald L. Rivest was elected a Fellow of the American Association for the Advancement of Science.

Professor Emeritus William F. Schreiber received the Society of Motion Picture and Television Engineers David Sarnoff Gold Medal Award.

Professor Stephen D. Senturia was named Barton L. Weller Professor of Electrical Engineering.

Professor Jeffrey H. Shapiro was elected a Fellow of the Optical Society of America.

Professor Arthur C. Smith was appointed Dean for Student Affairs.

Professor Gerald J. Sussman was named Matsushita Professor of Electrical Engineering. He also received ACM's Karl V. Karlstrom Distinguished Educator Award, in recognition of his outstanding contributions to introductory computer science education.

The International Federation for Information Processing gave its first Namur Award to Professor Emeritus Joseph Weizenbaum for his outstanding contributions to the creation of awareness of the social implications of information technology.

Several faculty were away this year:

Professor Dimitri Antoniadis spent the year studying topics in quantum electronics and semiconductor manufacturing.

Associate Professor Shafira Goldwasser spent the spring term writing a book on research in cryptography.

Professor Albert R. Meyer explored new research interests and began writing an introductory text for 6.044J during the academic year.

Professor William T. Peake studied the structure of animal ears during the academic year.

Professor Jack Ruina spent the spring term pursuing new research interests.

During the fall term, Professor Kenneth N. Stevens initiated new research, finished the late Dennis Klatt's book on acoustic phonetics, and began a new book on acoustic phonetic theory.

Associate Professor John N. Tsitsiklis explored new research interests during the spring term.

Professor Thomas F. Weiss spent the spring term working on a text for cellular physiology and biophysics.

We note with sadness the deaths of two members of our faculty.

Professor Edward L. Bowles died in September at the age of 92. Professor Bowles was a member of the EECS faculty from 1925-1952, when he transferred to what is now the Sloan School. Throughout the 1920s and early 1930s he was one of the key people who led this department into a strong program in communications, radio engineering and microwaves. Along with Ernst Guillemin, Carlton Tucker, and Julius Stratton he developed classroom and laboratory subjects in communications. Department Head Dugald Jackson asked them to set up a new integrated curriculum in 1933. He is also remembered for his major contributions to the government during World War II. He was Expert Consultant to Secretary of War Henry Stimson and Special Consultant to the Commanding General, Army Air Force. A result of this work he assumed a leadership role in establishing the Radiation Laboratory at MIT.

Professor James R. Melcher died in January at the age of 54. Professor Melcher was a member of our faculty since 1962, when he received his Ph.D. He was named Julius A. Stratton Professor of Electrical Engineering in 1981, an appropriate appointment since both he and Professor Stratton were eminent

teachers of electromagnetism. Professor Melcher specialized in electrodynamics and continuum electromechanics. His work has been applied to air pollution control, the measurement of fluid flows, the control of sheet glass thickness, the generation of electricity, and physiology. He was one of our best teachers, a dynamic, forceful lecturer who instilled enthusiasm into both his students and his colleagues. He was the author of several books, including his most recent (written with Institute Professor Hermann A. Haus) which came out a year ago. Professor Melcher possessed a high level of commitment to important social issues and he applied those values to both his personal and professional life. He often spoke out about matters of principle and integrity. He taught his students not only technical materials, but also showed them what it means to be an engineer and how to act professionally. At the time of his death Professor Melcher was the director of the Laboratory for Electromagnetic and Electronic Systems.

PAUL PENFIELD, JR.

Department of Materials Science and Engineering

SUMMARY

The academic year 1990-1991 has brought us a significant strengthening in our faculty and student body and in our funding base. We are once again recognized as the leading materials department in the country in surveys including the widely read U.S. News and World Report survey.

We have added two new faculty members to our ranks this year, and two more will join us in September 1991. Dr. Lionel C. Kimerling joined us as Full Professor last fall. He holds the Thomas Lord Professorship of Materials Science and Engineering. Dr. Kirk D. Kolenbrander also joined us last fall as Assistant Professor of Electronic Materials. He currently holds the Pirelli Career Development Chair. Dr. Gerbrand Ceder, now at the University of California, Berkeley, will join us in September as Assistant Professor of Materials Science and Engineering. Dr. David C. Dunand, a recent graduate of this department, will also join us in September as AMAX Assistant Professor of Materials Engineering.

Our ongoing undergraduate curriculum revision continues to make progress. We are pleased with continuing high student interest in our department at both the undergraduate and graduate level. At the graduate level, the high priority we have placed on providing graduate fellowships for incoming students is paying important dividends in graduate student recruiting. It is also critical to maintaining a high percentage of domestic students in our incoming class.

In 1991, Professor Ronald M. Latanision stepped down as Director of the Materials Processing Center after nearly seven years in that position. In leading MPC into the 1990's, Professor Latanision and his colleagues have generated a vision of materials processing in the U.S. which addresses a convergence of national priorities: the need to preserve a competitive industrial base, the national defense, the environment, energy resources, and to develop this nation's human resources. MPC, under the leadership of its new director, Professor Thomas W. Eagar, is prepared to move forward with vigor. Professor Latanision returns to the department to pursue his research and teaching, as well as his interests in K-12 education and public service.

We note with deep regret the death of Professor John F. Elliott on April 15, 1991. John was a distinguished educator, a major contributor to the field of chemical process metallurgy, and this country's recognized academic leader in the field of steel processing.

John studied for his doctorate under Professor John Chipman, and received the Sc.D. degree in Metallurgy from MIT in 1949. Then, after six years of valuable experience in the steel industry, he returned in 1955 as Associate Professor of Metallurgy. He became Full Professor in 1960. John received many honors in his long career, including

membership in the American Academy of Arts and Sciences, and the National Academy of Engineering. One of the finest tributes to John was by his students and colleagues at an international symposium on chemical process metallurgy held at MIT in his honor in June of 1990. It was a memorable occasion with featured papers on the future of process metallurgy in Asia, Australia, and Europe as well as in the Americas. A highlight of the event was the establishment of an endowed fund by the Iron and Steel Society and the Minerals, Metals and Materials Society in support of a John F. Elliott Lectureship in Chemical Process Metallurgy "...to honor Professor John F. Elliott for his many accomplishments and for the leadership he has provided over a career spanning more than four decades." At the same time, an endowed graduate fellowship, The John F. Elliott Graduate Fellowship in Chemical Process Metallurgy, was created at MIT in the Department of Materials Science and Engineering. We have been enriched by John Elliott's presence. His integrity and high standards remain as models for us.

THE UNDERGRADUATE PROGRAM

We now enter the third year of our five year initiative for undergraduate curriculum revision and textbook writing. During the first two years we have made much progress in developing cohesiveness in our undergraduate core subjects, eliminating overlapping material, and extending coverage where appropriate. We are increasingly aided in our efforts by the infusion of new young faculty members into our undergraduate core sequence. These faculty members bring expertise from newly developing areas within our field. This year has seen significant changes in our teaching of electronic materials to undergraduates and continuing important developments in our teaching of thermodynamics and kinetics.

A number of years ago the department undertook a major revamping of its laboratory offerings, with the aid of a grant of \$1 million from the Balfour Foundation. Out of that came a "two tier" laboratory sequence in which the first year was devoted largely to structure of materials. This laboratory, which cuts across all materials classes, has proved quite successful. The second tier of the laboratory sequence has comprised four laboratories dealing primarily with processing. These four laboratories are materials specific; that is, each deals with one specific materials class.

This year the faculty has concluded we may now be ready to teach a single materials processing-property laboratory that stretches across all materials classes. A special task force led by Professor Michael F. Rubner will prepare a report for faculty consideration in December 1991. If adopted, this new laboratory will replace the four materials specific "upper tier" laboratories.

Our undergraduate enrollment remains at historically high levels. Our sophomore enrollment last fall was in the mid-forties, and we expect a comparable number this coming fall. The growing importance of the field of materials will continue to provide ample career opportunities for increased numbers of undergraduates.

We continued during the last year our extensive recruiting efforts, including a 3-day Open House, our annual John Wulff Lecture, and direct mailings to the freshman class. Our IIIB (CO-OP) program continues to attract the majority of the undergraduate students in our department. Through this program we have strengthened our interactions with over 43 companies and government laboratories, while providing summer employment experiences for our undergraduates which are relevant to their educational development.

GRADUATE ADMISSIONS AND THE GRADUATE PROGRAM

We anticipate for the fall of 1991 a graduate class of about 190 students, about the same as a year earlier. Barring major funding difficulties, we anticipate slow growth in this number over the coming few years. A pleasing and remarkable change is that for the second year the percentage of students who have accepted our offer of admission has risen to above 60 percent compared with only about 50 percent in earlier years. Perhaps even more remarkable is that the percent of domestic students in these two incoming classes (fall, 1990 and fall, 1991) is between 65 percent and 70 percent compared with about 55 percent in earlier years.

We attribute the improved percentages noted above to two important factors. One is the active and involved Graduate Admissions Committee under the Chairmanship of Professor Kenneth C. Russell. The second is our decision to make graduate fellowships a top fund-raising priority of the department. We were able for the class of graduate students to be admitted in the fall of 1991, to offer 20 departmental fellowships of one semester or more, and we hope to be able to maintain or increase this number of fellowships awards in the years immediately ahead.

Approximately 30 percent of our graduate students are women, and 4 percent are underrepresented minorities. We note that a smaller percentage of the entering women are continuing to the doctorate, than of the entering male students. It is also true that domestic male students more frequently stop their education at the master's degree level than do foreign students who are more likely to proceed on for the doctorate.

We intend to continue to strengthen our funding base for fellowships in several ways. One of these is development of an "Industrial Fellows Program" which seeks industrial interaction in a form which includes sponsorship by the company of a graduate fellowship within the department. Another is seeking fellowship endowment, primarily to aid in attracting domestic graduate students to the field and to MIT. Endowment required to support a one-term fellowship is approximately \$300,000. Endowed fellowships in hand or being formed (including for example, The Nicholas J. Grant Fellowship, The John F. Elliott Fellowship, and The Ronald A. Kurtz Fellowship) now provide sufficient annual income for one-term fellowships for five students.

We are deeply grateful for having received last year a grant from the Starr Foundation sufficient to cover approximately 32 one-term

fellowships, to be used by our Graduate Committee over the coming three years. These fellowships are specifically to aid in attracting outstanding domestic students into our field.

We are disappointed that the special mailings and brochures which we have sent to minority colleges for the past several years have not produced an increased number of applicants. Nonetheless, we plan to continue our efforts and hope to see an increasing number of such students applying to our department in the future.

The distribution of our students among our six graduate degree programs and their affiliates is little changed from last year. As of February 1991 it was:

<u>Degree Program</u>	<u>Percent of Total Graduate Students</u>
Ceramics	17%
Electronic Materials	20%
Materials Engineering	20%
Materials Science	10%
Metallurgy	18%
Polymers	15%

Approximately 5 percent of our students in Materials Engineering were enrolled in our Technology and Policy Program, and 10 percent were enrolled in our Leaders for Manufacturing Program. Approximately 40 percent of our Polymer students were enrolled in our Program for Polymer Science and Technology.

PROFESSORSHIPS AND GRANTS TO ENDOWMENT

The continued strengthening of the department and the broadening of its programs have been made possible to a very great degree by the support of alumni and of industry. Faculty of this department now occupy nine endowed chairs. The chairholders are: H. Kent Bowen, Ford Professor of Engineering; Yet-Ming Chiang, Kyocera Associate Professor of Ceramics; Joel P. Clark, POSCO Professor of Materials Science and Engineering; Thomas W. Eagar, Richard P. Simmons Professor of Metallurgy; Merton C. Flemings, Toyota Professor of Materials Processing; Lionel C. Kimerling, Thomas Lord Professor of Materials Science and Engineering; Uday B. Pal, John Chipman Assistant Professor, Edwin L. Thomas, Morris Cohen Professor of Materials Science and Engineering; August F. Witt, TDK Professor of Materials Science and Engineering.

We note with gratitude the receipt of an endowed chair for a junior faculty member from AMAX Corporation entitled The AMAX Career Development Professorship in Materials Engineering. The chair will be held during the coming year by a new assistant professor, Professor David C. Dunand.

The department is proud to have received an additional endowed chair, to be filled beginning in the coming academic year. This chair is the Sumitomo Electric Industries Professorship in Engineering. We are also grateful for the establishment of The Harry C. Gatos Endowed Lectureship in Materials Science and Engineering, also established by Sumitomo Electric Industries Ltd., to recognize the pioneering work of Professor Gatos in electronic materials science and processing.

Term chairs, especially those held by junior faculty members, are of immense value in building their careers. Chairholders and chairs for the academic year 1990-1991 were: Stuart B. Brown, Richard P. Simmons Associate Professor of Materials Manufacturing; Peggy Cebe, Esther and Harold E. Edgerton Assistant Professor of Polymer Physics; Michael J. Cima, Norton Associate Professor of Ceramics Processing; Thomas W. Eagar, Leaders for Manufacturing Professor of Materials Engineering; Nicole Herbots, Carl Richard Soderberg Assistant Professor of Electronic Materials; Kirk D. Kolenbrander, Pirelli Assistant Professor of Electronic Materials, Andreas Mortensen, ALCOA Associate Professor of Mechanical Metallurgy, Manuel P. Oliveria, Elisha Gray II Assistant Professor of Materials Science and Engineering, Michael F. Rubner, Class of '57 Associate Professor of Polymer Physics.

FACULTY

During this academic year Professor Robert W. Balluffi received the distinguished Von Hippel Award of the Materials Research Society; he was also the Winchell Memorial Lecturer of Purdue University. Professor Michael J. Cima won the 1991 Extractive Metallurgy Science Award of the Minerals, Metals and Materials Society. Professor Peggy Cebe received an AT&T Research Initiative Award and a U.S. Army Summer Faculty Research Award. Professor Joel P. Clark was the keynote speaker of the Italian Transportation Association, Torino, Italy. Professor Morris Cohen was The Gilbert R. Speich Memorial Lecturer of the ASM International and The Inland Steel Company Lecturer at Northwestern University. He was Plenary Lecturer at the Chinese Society of Metals, Beijing, and delivered the opening lecture at the Mexico Academy of Materials Science spring meeting in Mexico City. Dr. James A. Cornie was co-recipient of the ASM 1990 Henry Marion Howe Medal.

Professor Thomas W. Eagar was Houdremont Lecturer of the International Institute of Welding, and also received both the Warren F. Savage Award and the William Spraragen Award of the American Welding Society. He was appointed Richard P. Simmons Professor of Metallurgy. Professor Merton C. Flemings delivered the Edward DeMille Campbell Memorial Lecture of the American Society of Metals and co-authored the Silver Anniversary Paper of the American Foundrymen's Society. He was a co-recipient of the Henry Marion Howe Medal of the ASM International, and recipient of the Merton C. Flemings Award of Worcester Polytechnic Institute. Professor Linn W. Hobbs was Program Chair for Materials Sciences for the Congress for Electron Microscopy. Professor Ronald M. Latanision was appointed distinguished Alumnus of Ohio State University and Visiting Professor of the University of Naples. Professor Frederick J. McGarry with student J. E. Moalli, received the Best Testing Paper Award at the 46th Annual Conference of the Society of the Plastics Industry, Composites Institute. Professor Andreas Mortensen was co-recipient of

the Henry Marion Howe Medal. Professor Manuel P. Oliveria was appointed to a career development chair established by Mr. and Mrs. Elisha Gray. Professor Julian Szekely received the distinguished TMS Educator Award and was Yugawa Memorial Lecturer of the Iron and Steel Institute of Japan.

Professor Cyril S. Smith received the prestigious Andrew Gemant Award of the American Institute of Physics for "...pioneering the use of solid state physics in the study of ancient art and artifacts to reconstruct their cultural, historical and technological significance." Professor Edwin L. Thomas received the High Polymer Physics Prize of the American Physical Society "...for his outstanding contributions to elucidation of microstructure in polymeric materials through development and application of innovative electron microscopic techniques." Professor Thomas delivered the John Wulff Lecture at MIT, and the Fraser Price Lecture at the University of Massachusetts. Professor Carl V. Thompson received a U.K. Science and Engineering Research Council Fellowship for Study at the University of Cambridge, England. Professor Harry C. Tuller received a Fulbright Travel Grant for Research in Paris, and was appointed Visiting Professor at the Universitie Pierre et Marie Curie, Paris, France. Professor August F. Witt was appointed TDK Professor of Materials Science and Engineering.

UNDERGRADUATE STUDENTS

The Student Undergraduate Materials Society (SUMS) continued to be a significant source of strength for the undergraduate program. SUMS assisted in end-of-term subject evaluations, planned socials, and assisted in tutoring of fellow students. Officers of the society during the fall semester were Richard Wong (President), Michelle Hou, (Vice President), Albert Cheng (Secretary), and Ana Jamashidi (Treasurer). New officers elected in spring 1991, are: Scott Jacobsmeyer (President), Karina Rigby (Vice President), Andrea Wang (Secretary), and Lawrence Foley (Treasurer).

Two students, Bonnie Kao and Terry C. Totemeier were invited to join Phi Beta Kappa. The fall initiates for The Tau Beta Pi Engineering Honor Society were: Darren Castro, Janelle Gunther, Scott Jacobsmeyer, Jeanette Ryan, Barbara Sweet, Weejyn Tan, and Shu-Yuan Tung (Class of '92); and Cheryl Klepser and Susanne Perutz (Class '91). Lynore M. Abbott received the Best Undergraduate Thesis Award. Darren T. Castro received the American Legion General Scholastic Excellence Award and the ROTC Bronze Medal from the Society of American Military Engineers. James Neely was awarded the Nunzio Barberese Commemorative Scholarship in recognition as an outstanding Alfred University Ceramic Graduate. Terry C. Totemeier received a Marshall Fellowship for study in the United Kingdom. Richard P.-Y. Wong received the Best Cooperative Project Report Award.

GRADUATE STUDENTS

Newly elected members of the Graduate Materials Council (GMC) are: Chris Coronado (Chairman), Donna McCoy (Vice Chairman), Isako Hoshino (Treasurer), Bruce Pint and Rick Mlcak (DCGS Representatives), Robert Calhoun and Frank Ross (Social Chairs), Tami Fletcher (MPC)

Representative), and Ali Farah (MESS Seminars). GMC continued its seminars and monthly socials. It continued to undertake the supervision of the arduous task of course evaluations.

The MIT Chapter of the Materials Research Society has the same officers as last year. They are Sergio Ajuria (Chairman), Ann Westerheim (Secretary), and Jerry Floro (Treasurer). New officers elected in spring 1990 are Bethanie Hills (Chairman), Mariflor Salas-Morales (Vice Chairman and Treasurer), and Julie Tsai (Secretary). The group organized a series of lectures on Materials Research in Industry, with speakers discussing opportunities in materials research at their respective companies.

Jimmy K.-W. Chen received an AT&T Bell Laboratories Doctoral Scholarship. Sossina M. Haile received the Award of the New England Section of the American Association for Crystal Growth for "the outstanding student paper and presentation on work relating to the theory or practice of crystal growth." She also received the Graduate Student Award of the Materials Research Society and a Fulbright Fellowship for the coming year. Olof C. Hellman received the European MRS Student Award, Strasbourg, France. Cheryl Ann Klepser received the Gold Award from the MIT Athletic Department. Qing Ma received the Materials Research Society Award for his Graduate Student Research Paper. John Moalli along with Professor Frederick J. McGarry received a Best Paper Award at the 46th Annual Conference of the Composites Institute of the Society of the Plastics Industry. Susan C. Noe was selected for the Best Student Paper in Plastics Analysis by the Society of Plastics Engineers. Elliott Schwartz received the John Wulff Award for Excellence in Teaching. Students were awestruck by his dedication and performance in the senior level transport course for which he was teaching assistant. Deborah L. Vezie was named an Electron Microscopy Society of America Presidential Scholar and was also awarded a scholarship to the NSF/ASU winter school on high resolution electron microscopy. John Wlassich received an NSF Japan Program Summer Fellowship. Chuxin Zhou received the Student Poster Award of the Canadian Institute of Metallurgists.

Fellowship Awards for one or more semester were held during academic year 1990-1991 by 43 students. They were: Heather E. Inglefield and Lara A. Touryan, Nicholas J. Grant Fellowship; Stephen H. Foulger and Susan Noe, IBM Fellowship; Karen T. Ho, Michael C. Zody, and Yonggang Rin, Kurtz Fellowship; Michael L. Dorah, Tracy L. Harrison, Julia C. Putnam and Michele W. Sequeira, Leaders for Manufacturing Fellowship; Maureen T. Fahey and Bethanie J. Hills, Carl Loeb Fellowship; Jeffrey D. Carbeck and Libby K. Louie, PPST Fellowship; Hiu Kok Au, Nancy Frier Dean and Michael Zody, R. Rocco Fellowship; Brian R. Bennett and Robert B. Calhoun, SCEEE Fellowship; Russell Klehn, Welding Research Council Fellowship; Lynn L. McDonough, Department Endowed Fellowship; Jerrold A. Floro and Mary Matthiesen, AT&T Bell Laboratories Fellowship; Heather L. B. Shapiro, Fannie and John Hertz Foundation Fellowship; Steven A. Attanasio, Katherine C. Chen, Naomi Super Fried, Michael Liberatore, and Elliott Schwartz, National Defense Science and Engineering Graduate Fellowship; Monica Slocum Kaforey, Elizabeth J. Earhart, and Stephanie

Simmons, NSF Fellowship; Jeri Ann S. Ikeda, Angela S. Longo, Donna S. McCoy, and Chrysanthe Terwilliger, ONR Fellowship; Eddy K.-Y. Tan, Sir Run Run Shaw Fellowship; Yuying Tang, Wang Fellowship; Catherine M. Heremans and O. Vancauwenberghe, DeCorte Fellowship; Timotheus S. Smit, AKZO Fellowship; Satyavolu S. Papa Rao, Intel Foundation Graduate Fellowship.

FACULTY AND STAFF RESEARCH ACTIVITIES

During the past year Professor Samuel M. Allen continued his research on intermetallic compound alloys, including work on a new program with Dr. James D. Livingston on slip, twinning and transformations in Laves-phase strengthened alloys. Professor Benjamin L. Averbach continues work on development of new bearing materials for the next generation of engines. Professor Robert W. Balluffi has succeeded in experimentally measuring and theoretically calculating grain boundary diffusivities in the Au/Ag system. Reasonably good agreement was obtained. His major effort for the year has been writing the textbook, "Intercrystalline Interfaces," in collaboration with Dr. Adrian Sutton of Oxford University. Professor Michael B. Bever has continued his research and editorial activities involving materials economics, materials policy, conservation, and recycling. Dr. Paul D. Bristowe's research is focussed on Monte Carlo calculation of grain boundary segregation, and construction of new interatomic potentials for covalent solids.

Professor Stuart B. Brown has identified major fallacies in current techniques used to evaluate rate dependent constitutive behavior. Additional advances include the application of nonlinear control concepts for the prediction of dynamic recrystallization, and improved constitutive models for semi-solid and high homologous temperature flow behavior. Professor Peggy Cebe has developed a technique using dipole reorientation to study molecular mobility of the crystal-amorphous interphase region in high performance semicrystalline polymers. Her research effort on development of structure through processing has been expanded to include novel polyimides and their blends with liquid crystalline polymers.

In the past year, Professor Yet-Ming Chiang and his students have found exciting new behavior at grain boundaries and surfaces in the commercially important ceramics, titanium dioxide, whereby the electrical potential can be "titrated" in sign and magnitude by lattice doping. Professor Joel P. Clark's research in the Materials Systems Laboratory (MSL) has concentrated on analyzing the economics of automotive materials and on policy alterations for materials recycling. Professor Morris Cohen's study of nanocrystalline defect-free iron-cobalt particles show that martensitic transformation in these materials is homogeneously nucleated. Dr. James A. Cornie's research on mechanics, synthesis and properties of inorganic composites is now being applied to the integrated design of Ti matrix composite components in new Air Force Materials Laboratory Manufacturing Science programs. During the past year Professor Thomas W. Eagar has developed new techniques for brazing aluminum metal-matrix composites, and shown the feasibility of Low-Temperature Transient Liquid Phase Diffusion Bonding which is already finding application in several areas of electronic packaging. Professor Merton C. Flemings' research on solidification

processing included continuing studies on rapid solidification, metal matrix composites, and directional solidification of high temperature superconductors. Professor Nicholas J. Grant's research on rapid solidification, continuous spray deposition processing of simple, low alloy steels and broadly based aluminum alloys will be the base for pilot plant, continuous spray deposition processes jointly funded by DOE and the industrial participants

Dr. John S. Haggerty's research focuses on the processing and properties of monolithic and composite ceramics made from high purity ceramic powders and polymeric precursors. He has initiated research programs in growth of oxide single crystals for use as reinforcements of metal and ceramic matrix composites and as high T_C superconductors. Professor Nicole Herbots reports the formation at room temperature by low energy Ion Beam Oxidation (IBO) and Nitridation (IBN) of new dielectrics based on SiGe. Professor Linn W. Hobbs' research on high temperature corrosion has provided a new refractory metal alloy which exhibits simultaneous oxidation and sulfidation corrosion resistance comparable to the best oxidation resistance of stainless steels (which degrade rapidly in sulfur-bearing environments). Dr. Olusegun J. Ilegbusi continues to apply mathematical methods to model complex transport phenomena in materials processing operations. He has initiated a new research on the optimization of the thermal characteristics of metal-matrix composites used as heat sinks in electronic modules. Professor Keith H. Johnson has continued his research on the mechanism of high T_C superconductivity.

Professor Lionel C. Kimerling's studies of semiconductor processing addressed reactive ion etching (RIE) and showed that the anomalous degradation of electronic transport properties below the etched surface is controlled by the diffusion-limited trapping of interstitial defects and impurities. His group has introduced a new technology of silicon optoelectronic devices which employs rare earth doped silicon material for light emitters and amplifiers. Professor Kirk D. Kolenbrander has assembled his laboratory and begun work on the synthesis and processing of semiconductor quantum dot materials. Using novel gas-phase techniques he is combining elements of synthesis and characterization in investigation of these new materials. His research is dedicated to the investigation of a class of new materials which show promise for photonic switching. Professor Ronald M. Latanision determined electronic properties of passive films on Fe-Cr alloys by photoelectrochemical techniques. Measurement of the flat band potential for the passive films on the different alloys indicated that the passive film is doped increasingly n-type as the Cr concentration in the base alloy is increased.

Professor Heather N. Lechtman continues her research in the field of prehistoric technologies of the Andean culture area, with an emphasis on the early metallurgies of those societies. She is currently investigating the properties of Cu-As alloys and the prehistoric smelting regimes used to win copper-arsenic bronze from Andean tetrahedrite ores. Professor Frederick J. McGarry has developed several ways to fundamentally improve the properties of sheet molding compound

(SMC). Research in Professor Andreas Mortensen's group has included continuing work on infiltration of fiber preforms and study of the kinetics of hot-pressing of titanium matrix composites. He has also studied the plasticity of reinforced materials combining theoretical work with experimental data using dislocation decoration in reinforced silver halides. Related work has included mechanical properties studies, and study on solidification of composites. Professor Manuel Oliveria is nearing completion of a thin film system that will be used to examine the processing and properties of magnetic and optical thin films. Of primary interest is the interface contributions to the performance of these materials.

Professor Uday B. Pal is developing synthetic fluxes for refining ferrous melts, and has conceptualized a novel electrochemical technique for rapidly extracting oxygen, sulfur and phosphorous from molten metals. He is extending the use of the electrochemical vapor deposition process as an experimental and analytical tool to determine defect structures and solid state transport parameters in oxides which are difficult to measure by other experimental techniques. Professor Regis M. N. Pelloux's work is centered around the study of fatigue and fatigue fracture behavior of metals. Including work on the aging of aircraft structures and application of failure analysis techniques to fuselage cracks, the high temperature performance of titanium aluminides up to 700°C was investigated in creep and in fatigue. Professor David C. Ragone has completed a first draft of a new text for teaching sophomore thermodynamics to materials science students. Professor Robert M. Rose conducted research in collaboration with Professor Donald R. Sadoway on electrochemical modulation and electrosynthesis of high temperature superconductors. Professor David K. Roylance's research is centered on process-structure-property investigations of polymers and composite materials.

Professor Michael F. Rubner's group has fabricated for the first time, a Schottky barrier device based on a dopant modulated thin film organic superlattice. The active element of the device was comprised of molecular layers of a heavily doped conductive polypyrrole alternating with molecular layers of a lightly doped poly(3-alkyl thiophene). Rubner's group has also developed two new techniques suitable for fabricating multilayer thin films of conducting polymers. Professor Kenneth C. Russell developed a theory for the thermodynamics and kinetics of the interactions between ceramic fibers and molten or solid intermetallic compounds. Professor Donald R. Sadoway began a major initiative to develop environmentally benign metal extraction technologies based upon direct electrolysis in molten oxide media. Professor Julian Szekely's accomplishments during the year include the development of a model for the impaction and spreading of metal droplets in the spray forming process and experimental verification of these calculations, using high speed photography. Research is continuing on the planning of an in-flight experiment, using the space shuttle in 1994. Professor Edwin L. Thomas' novel approach using minimal and constant mean curvature surfaces as models for the intermaterial dividing surface in block copolymers and block copolymer-homopolymer blends continues to be a fruitful area of research. Professor Carl V. Thompson has developed improved microstructure-sensitive models for the reliability of thin film metallization for applications in integrated

circuits. He has also begun development of a thin film process/reliability simulator, which allows computer simulation of microstructural evolution during film deposition and during post-deposition and post-patterning annealing.

In Professor Harry C. Tuller's research, investigation of the transport properties of a number of the high temperature superconducting cuprates at elevated temperatures has led to an improved understanding of the defect structure and consequently the mechanisms for oxygen transport. During the past year, Professor John B. Vander Sande's major research efforts have been in the area of increasing the current critical density of high temperature superconducting oxide ribbons being produced in his laboratory. Results indicate that deformation processing of the metallic precursors, oxidation-annealing conditions, the sequence of deformation-oxidation-annealing, and alloy oxidation are important factors influencing superconducting properties. Professor August F. Witt's research is now emphasizing advancement of non-invasive semiconductor characterization. Digital, semi-insulating GaAs wafers were analyzed using NIR transmission microscopy with computational image analysis in darkfield mode. They are found to exhibit in all instances a high density of precipitates which appear as decoration on dislocations

Professor Bernhardt J. Wuensch has obtained extensive data for anion self-diffusion in MgO, providing a more precise value for the activation energy. Results indicate that an interstitial mechanism is operative rather than the vacancy process that one would intuitively anticipate. In search for a new alkali-ion fast-ion conductor, a rich variety of K-Nd silicates have been synthesized by hydrothermal techniques. Professor Ioannis V. Yannas has continued studies of regeneration of the rat sciatic nerve by use of porous collagen-GAG (CG) bridges. Clinical studies of the artificial skin with 106 patients have yielded immunological and histological data.

MERTON C. FLEMINGS

Department of Mechanical Engineering

INTRODUCTION AND PERSPECTIVE

The mechanical engineering profession is broadly concerned with energy, motion and materials, and the design, production, and management of systems to meet the needs of society. The profession has a central role in addressing the challenges of the future relating to the supply and efficient utilization of energy, enhancement of the environment, the manufacture and production of goods and services, safe and efficient transportation, and health care and human rehabilitation. Mechanical engineering practice is changing rapidly due to the increasing capabilities of computation, information processing, measurement and control technology, the continued development of the fundamental disciplines, the growing ability to synthesize new materials and processes, and an improved understanding of the life sciences and human factors. These rapid changes provide both significant challenges and opportunities to the profession and for the education of future engineers.

Student interest in mechanical engineering continues to be strong. The Department has the second largest undergraduate enrollment at MIT with more than 440 undergraduates. In the graduate program approximately 45% of the 407 full-time students are enrolled in the PhD program.

Special effort this year has been focused on undergraduate and graduate curriculum development in the department. New materials have been introduced to provide design experiences in the core undergraduate subjects and new computational techniques have been developed for subjects in the undergraduate and graduate curriculums.

This spring the second class of 32 students has graduated from the Leaders for Manufacturing Program which is a combined two-year education and research program leading to joint SM degrees in engineering and management. As a part of the program students perform thesis research at one of the eleven cooperating industrial organizations. Twelve faculty from the department participate actively in this program and approximately 50% of the students in the program are associated with mechanical engineering.

Faculty in the design area are developing a new graduate education program -- the New Product Development Program -- which leads to an SM degree and involves direct interaction with industry to gain experience in the processes of new product development.

Faculty efforts in identifying and developing research programs in the past year have been notable, particularly in light of the overall support/cost picture. Research support from industry has continued to be significant, representing approximately 25% of the total research administered through the Department.

Effort is continuing to be devoted to the development and improvement of facilities and equipment in the Department. Teaching laboratories have been enhanced with the acquisition of new computers and additional equipment has been acquired for the manufacturing laboratory.

The Fluid Mechanics Laboratory renovation has been completed to provide enhanced capabilities in fluid mechanics research related to fundamental flow studies and to applications in the biomedical and environmental engineering areas. Additionally, plans to expand the teaching and research facilities in the Martin Center for Engineering Design have been formulated and received preliminary approval.

PROGRAMS OF INSTRUCTION

Objectives

The Department instructional programs strive to educate mechanical engineers for leadership roles in professional practice and engineering education, and to provide a broad flexible background for entering related fields such as medicine, law, management, and public policy. Programs emphasize a basic foundation in the engineering sciences combined with a strong design and laboratory experience which couples theory and analysis with the physical world. At both the undergraduate and graduate levels, involvement of students with faculty in research at the forefront of engineering practice -- through special projects, the Undergraduate Research Opportunities Program (UROP) and theses -- is a hallmark of the Department.

UNDERGRADUATE PROGRAMS

Organization

The Undergraduate Program is organized with Professors David Gordon Wilson and Peter Griffith as the Undergraduate Officers and Professor Ernest Rabinowicz as the Scheduling Officer, who are responsible for organizing and coordinating the Undergraduate Program and the scheduling and staffing of undergraduate subjects. The Senior class Registration Officer is Professor Peter Griffith; the Junior class Registration Officer is Professor Carl Peterson; and the Sophomore Registration Officer is Professor Warren Seering. Professor Thomas Sheridan is the Advisor for Course II-A, and Professor Igor Paul is the Advisor for Course II-B. Ms. Peggy Garlick is the Undergraduate Programs Administrative Assistant.

Degree Programs and Enrollment

The Department undergraduate program leads to the SB in Mechanical Engineering (Course II), which is accredited by the Accreditation Board for Engineering and Technology (ABET) or the SB without specification (Course II-A), which is not ABET accredited. Course II-A provides an alternative to the regular mechanical engineering program and is intended for those students who wish to design a special program coupling areas such as biomedical engineering, management, and energy policy with mechanical engineering. Course II-B, the Engineering Internship Program, leads to the SB and SM in Mechanical Engineering with industrial experience as an integral part of the program.

The Department total undergraduate enrollment is more than 440 students. The new sophomore class of 132 included 24 women and 12 black students. Sixteen sophomores enrolled in II-A.

In the 1989-90 academic year the Department awarded 158 SB degrees with 128 in Mechanical Engineering (II), 10 without specification (II-A), and 20 in the Internship Program (II-B).

Undergraduate Curriculum Development

During the year effort continued on undergraduate curriculum development with activities devoted to the introduction of design into core undergraduate subjects in mechanics and materials and in the review of our senior required subject in design. This review has recommended that the senior design subject be broadened to provide a more strongly integrated experience which spans the disciplines in the department.

Faculty have also continued in the development of the core manufacturing subject and have nearly completed preparation of an undergraduate manufacturing textbook, *Manufacturing Engineering*. A special summer subject based on the core manufacturing subject has been offered through the American Society of Engineering Education so that experiences in the manufacturing area might be shared among engineering educators from a number of schools.

Significant efforts continued in upgrading undergraduate laboratories with the development of new laboratories in manufacturing and in instrumentation and measurement.

A new restricted elective subject has been developed by Professor M.C. Boyce which emphasizes computational techniques in mechanics, 2.33 Finite Element Applications in Mechanics and Materials.

A group of Department faculty and colleagues from MIT joined with faculty from six other universities (Howard University, Morgan State University, Pennsylvania State University, CCNY, University of Maryland and University of Washington) to form a coalition to improve engineering education and to attract more students, particularly from underrepresented groups, to engineering with support from the National Science Foundation for a five year period. The coalition, Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL) will develop new engineering curricula, multi-media educational modules and outreach programs to students and teachers in high and middle schools.

Student Organizations

The Student Chapter of the American Society of Mechanical Engineers continued to develop student professional activities in the Department under the leadership of its officers: David Gerson, President; Chris Harris, Vice-President; and Bruce Padmore, Treasurer. Professor Igor Paul served as the Faculty Advisor to the ASME student members. This spring MIT served as host for a meeting of ASME student sections from the Northeast Region.

Black ME is an organization of students which provides a supportive environment for minorities in the Department. This past year the organization provided academic support in subject reviews. The organization was ably led by

Andrew Frazier, President; John Grooms, Vice-President; Alvin Ramsey, Secretary; and Elianne McMahon, Treasurer. Professor David Gordon Wilson was the group's Faculty Advisor.

Pi Tau Sigma, the mechanical engineering honorary society, continued its tradition of fostering student-faculty relations and serving the Department through its course and instructor evaluation program. Activities during the year included chapter meetings, classroom evaluations at mid-term and end-of-term, and a spring banquet to honor newly elected members. The organization was led by: Don Lee, President; Sarath Krishnaswamy, Vice President; Henry Dotterer, Secretary; and Russell Stevens, Treasurer; with Professor Derek Rowell acting as Chapter Advisor. Professor Ernest Rabinowicz was Faculty Advisor for the Student Chapter of the Society of Manufacturing Engineers which had as its officers: Alexander Denner, President; Chris Passow, Vice-President; and Anthony Duros, Treasurer.

Student Awards

Many undergraduates in the Department were recognized for academic excellence, engineering creativity, and community service.

Luis De Florez Awards were made to David-Henry Oliver, Andrew Heafitz, Lon van Geloven and Jason Silver.

Laurette Gabour was awarded the Reinhold Rudenberg Memorial Prize.

Todd A. Simson and Shin J. Choi shared the Whitelaw Prize for innovative and inspiring design.

Amoco Foundation Scholarships were awarded to Gary K. Porter, Jon D. Demerly and Andrew D. Yablon.

David Gerson received the ASME Student Section Service Award and the International Gas Turbine Institute Award.

The ASME Sylvia W. Farny Scholarship was awarded to Alvin L. Ramsey, Jr.

The Wunsch Foundation Silent Hoist and Crane Awards were given to Brandt C. Casey, Vincent Di Palma, Shih-Hao Lai, Jennifer L. Lopez, Sharon L. Marcadis, William S. Schnorr, Kristin Slanina, John E. Gilbert and Kent R. McCord.

GRADUATE PROGRAMS

Organization

The graduate program has been directed by Professors Ain A. Sonin, Graduate Policy and Registration Officer, and John Lienhard V, Graduate Admissions Officer. Ms. Leslie Regan is the Graduate Administrative Assistant.

Degrees

The Department offers the SM degree in Mechanical Engineering, the undesignated SM degree, the degree of Mechanical Engineer, and the doctorate in Mechanical Engineering. The undesignated SM degree allows students to pursue special interdisciplinary programs as well as programs which are more specialized than those satisfying the designated degree requirements.

Enrollment and Degrees Granted

Graduate enrollment in the fall of 1990 was 407 full-time students including 46 women, 2 black, 5 Hispanic, and 14 Asian-American students. In September 1990, 213 new students were admitted from 544 applicants, with 133 students registering.

In 1990-91 the Department awarded 109 SM degrees (of which 13 were combined SB/SM degrees), one Mechanical Engineer degree, and 41 doctoral degrees.

In Fall 1990, 93% of all graduate students received support from the Department, MIT funds, fellowships, the government or industry with sixty eight percent of the graduate students supported by the Department through research and teaching assistantships.

Graduate Curriculum Development

Effort continued in the development of graduate curriculum in the area of manufacturing. This effort was coordinated with the Leaders for Manufacturing Program which is an interdepartmental program leading to joint SM degrees in engineering and management. Many students in the program enroll in subjects in the Department in the areas of manufacturing processes, automation, and systems, as well as design for manufacturing.

A new graduate education program is being developed by faculty in the design area. This program - New Product Development - will lead to an SM degree in Mechanical Engineering with students taking subjects in both engineering and management. The program is coupled strongly to industry with students undertaking the development of new products to learn explicitly about the new product development process.

Three new subjects have been added to the curriculum for next year: 2.292 Environmental Control Technology, taught by R. F. Probstein, 2.79J Biomaterials - Interaction, taught by I. Yannas and M. Spector and 2.953J Ethics in the Workplace and in Research, taught by C. Whitbeck and T. Sheridan.

A graduate level text book has been prepared by Professor Nam Suh entitled "Principles of Design" and Professor J.-J. Slotine and Dr. W. Li have published the second edition of the text "Applied Nonlinear Control."

Professor George Chryssolouris has published the text, "Laser Machining-Theory and Practice."

Student Awards

Andrzej C. Skoskiewicz and David R. Wallace shared the Carl G. Sontheimer Prize for Innovative Design in Mechanical Engineering.

Honor Jones Passow was granted the Martin Fellowship for Engineering Design, and John B. Morrell was awarded the Warren M. Rohsenow Fellowship.

RESEARCH

Activity Areas and Support Levels

Research in the Department varies from very basic, fundamental research to the conception, design, and prototype evaluation of innovative systems to serve the needs of society. The majority of the faculty are explicitly involved in basic research, and almost every research project in the Department has a fundamental component. Fundamental disciplinary research is conducted in the areas of mechanics and materials, the fluid/thermal sciences, and dynamic systems and control. Applications research is focused in areas of energy and the environment, manufacturing and processing, bioengineering, and systems and design. In the last few years, the areas of most significant growth have been manufacturing and processing.

The total volume of sponsored research for the 1990-1991 year administered through the Department is \$7.8 million, approximately a 6% reduction from the volume last year. Additional sponsored research of an approximately equal amount is administered through interdepartmental laboratories and centers in which Department faculty participate. These centers include the Energy Laboratory, the Laboratory for Manufacturing and Productivity, the Materials Processing Center, the Health Sciences and Technology Program and the Center for Transportation Studies. The trend of the last few years of a significant portion of research supported by industry has continued, and approximately 25 percent of the research in the Department is supported directly by industrial organizations.

RESEARCH ACCOMPLISHMENTS

Manufacturing, Materials and Mechanics

The major Department activities in manufacturing and processing are associated with the Laboratory for Manufacturing and Productivity (LMP). This laboratory is a focus for research which systematically explores the complex interactions in design and production and involves faculty in automation and robotics, computer-aided design and manufacturing, metals and polymer processing, flexible materials, and tribology. Within the Laboratory Professor Nam Suh has continued to make significant progress in the development of design axioms for manufacturing processes while Professor George Chryssolouris has developed techniques to aid in the scheduling and planning of

manufacturing processes. Dr. Stanley Gershwin has continued the development and evaluation of models for manufacturing production lines. Professor David Hardt has conducted research to improve welding and sheet metal forming processes through the direct application of automatic control techniques, while Professor Ely Sachs has initiated a program in rapid prototyping of mechanical components. Research in polymer processing has been performed through the MIT-Industrial Polymer Processing Program by Professor Timothy G. Gutowski in composite materials fabrication. Additionally, Professor Jung-Hoon Chun has initiated a research program to evaluate spray-forming techniques in composites manufacturing. Professor Stanley Backer has developed improved methods to characterize the behavior of flexible and composite materials. An industrial consortium, under the direction of Professor Ernest Rabinowicz and Dr. Nannaji Saka, has supported basic research in tribology related to magnetic recording devices and mechanisms of friction and wear.

In the Mechanics and Materials area, research conducted by Professors Ali Argon, Frank A. McClintock, David Parks, Lallit Anand, Mary C. Boyce, and Rohan Abeyaratne is seeking to develop a better quantitative understanding of the mechanical behavior of materials including inelastic deformation, fracture, and thermo-mechanical coupling effects. Applications of the fundamental analytical techniques and basic experimental studies have been conducted for hot-forming of metals, inelastic response of glassy polymers, development of physically based models of creep damage, mixed-mode elastic-plastic crack propagation, and interfacial behavior in metal matrix composites and for shape memory alloys.

In the mechanics area Professor James H. Williams, Jr. is developing nondestructive evaluation techniques for composite materials using acoustic emission techniques, and Professor Stephen Crandall is developing analytical techniques for evaluation of rotor-bearing systems.

Computation Methodologies and Techniques

Several faculty are developing fundamental computational and analytical tools. Professor Klaus-Jurgen Bathe is developing finite element methods for fluid-structure interactions, while Professor David Parks is developing finite element methods for characterizing fracture. Professor Patera is developing spectral element methods for internal flows and Professor Ghoniem is developing vortex element methods for turbulent, compressible flows.

Energy and the Environment

A number of faculty have conducted research on the development of advanced analytical and experimental techniques related to energy production and conservation and preservation of the environment.

Research in the REMERGENCE Laboratory, has been conducted by Professor Michael P. Cleary to evaluate rock fracture related to oil and gas extraction and by Professor Carl Peterson to improve mining systems.

In the heat and mass transfer area, Professors Tony Patera and Bora B. Mikic have performed analyses, corroborated by experimental data, which indicate that substantial augmentation of heat transfer rates may be achieved by modulating unsteady flow in channels, while Professor John H. Lienhard V has developed experimental capabilities to evaluate significantly improved heat transfer

rates through jet impingement techniques. Professor Shahryar Motakef is conducting studies of heat and mass transfer in crystal growth. Experimental studies to characterize two phase gas-liquid flows associated with power systems have been conducted by Professor Peter Griffith with particular application to the electric power industry, while Professor Harri Kytomaa has developed experimental capabilities for the study of multi-component solid-liquid flows.

Research in the Sloan Automotive Laboratory, supported by several industrial consortiums, is evaluating the uses of ceramic materials in engines and is developing improved understandings of combustion processes through basic analytical and experimental research. This effort involves Professors John B. Heywood, James C. Keck, Wai K. Cheng, and Ahmed P. Ghoniem and is complemented by basic research in engine lubrication conducted by Dr. David P. Hoult.

Research in the Cryogenic Engineering Laboratory, led by Professor Joseph L. Smith, Jr. and Dr. Yukikaza Iwasa, has led to the development of a prototype superconducting generator and high performance cooling systems for superconducting magnets. A research program has been initiated by Professor Markus L. Flik to determine the heat transfer characteristics of thin film super-conducting materials.

Research focusing on the environment includes the work of Professor Ronald F. Probst who is investigating the treatment of ground water at hazardous waste sites using electroosmotic techniques. Additionally, Professor Ain Sonin has conducted research to determine the transport of heat and mass transfer across vapor-liquid surfaces in low gravity environments.

An industrial consortium to support research in structural acoustics has been formed under the leadership of Professor Richard Lyon. Research in the fundamental areas of ocean waves and acoustic propagation has been conducted by Professor Triantaphyllos Akylas and Professor Patrick Leehey.

Biomedical Engineering

Research in biomedical engineering has had encouraging progress in areas related to human mobility and sensory aids, treatment of tumors via hyperthermia, development of artificial skin, and development of an understanding of the fluid mechanics related to the cardiovascular, pulmonary, and ocular systems.

In the Eric P. and Evelyn E. Newman Laboratory for Biomechanics and Human Rehabilitation, Professor Robert Mann directed research in which experimental measurements were made of the pressures in a human hip joint to identify sources of major loading on the joint. Effort to develop aids for the handicapped has been continued by Dr. Michael Rosen, while Professor Neville Hogan has studied the factors influencing the role of feedback in human limb motion. Professor Will Durfee has conducted research in the processing of electro-myographic signals for the control of human prostheses, and Professor Derek Rowell has initiated research in medical image processing.

Professor Ioannis Yannas' research has shown significant progress in the development of bio-compatible artificial skin for severely burned patients and materials to regenerate nerves.

In the Laboratory for Medical Ultrasonics, Professor Padmakar Lele has continued research to develop techniques for the treatment of tumors through controlled hyperthermia using focused ultrasound.

Biomedical research in the fluid mechanics laboratory conducted by Professor Roger Kamm and Dr. Mark Johnson is directed to developing a basic understanding of the hydrodynamics of solutions in the eye related to diseases such as glaucoma. Professors Ascher Shapiro and Kamm are collaborating on research to understand the flows in lung passages. Research by Professor C. Forbes Dewey on identifying the genesis of arteriosclerosis has continued with experimental quantification of arterial flows, while research by Professor Ernest G. Cravalho has focused on the influence of freezing and thawing of tissues.

Systems and Design Research

Systems and design research is concentrated in the Center for Information-Driven Mechanical Systems, the Man Machine Systems Laboratory, the Computer-Aided Design Laboratory, and the Martin Center for Engineering Design. Professor Thomas B. Sheridan is continuing the development of methods for characterizing human interactions with telerobots. Professor David C. Gossard is developing expert systems technology and designer-machine interfaces to enhance computer-aided interactive design functions.

Significant progress has been made in the robotics area. Professor Harry Asada has initiated research on issues of learning/teaching in robotic systems, while Professor Jean-Jacques Slotine has demonstrated methods of nonlinear control to improve robot performance under widely varying load conditions. Professors Steven Dubowsky and Igor Paul have developed experimental facilities for the detailed evaluation of the performance of manipulators mounted on mobile platforms, as might occur in spacecraft applications. Professor Neville Hogan has continued the development of techniques to characterize robots interacting with their environments using advanced modelling techniques, while Professor Harry West is developing braced manipulator techniques.

Professor Warren Seering has continued effort on the development of control systems to suppress vibrations in flexible mechanical systems, while Professor Kamal Youcef-Toumi has demonstrated the development of time-delayed control systems for the control of highly nonlinear actuators.

In transportation, Professor David N. Wormley has continued research on the nonlinear behavior of rail vehicles, as well as nonlinear models for the evaluation of automotive vehicle safety and performance.

Research to utilize artificial intelligence techniques to aid in the design process has been conducted by Professor Seering, while research on human-computer interface in the design process has been initiated by Professor Mark Jakiela.

Professor David Gordon Wilson is investigating the innovative uses of video-disk technology in design, while Professor Woodie Flowers and instructor James Grinnell have continued efforts to develop visual representations to aid in the design process.

DEVELOPMENT FUNDS

The Department has benefited significantly from a number of donations and grants given by MIT Alumni, friends, foundations and industrial organizations. These discretionary funds have been used as seed funds to initiate new research areas, to acquire equipment for education and research, and to enhance young faculty development. Grants from the du Pont Corporation, Shell Corporation, Exxon, and Procter and Gamble have been of considerable assistance to the Department.

FACULTY AND STAFF

Size and Composition

On September 1, 1990, there were 58 full-time faculty; 31 professors, 18 associate professors, (13 with tenure), and 9 assistant professors. The teaching, research, and technical staff fluctuates around 70, more than half of whom are part-time.

Organization and Management

The Department is organized in three disciplinary Divisions: Division I, Mechanics and Materials; Division II, Thermal and Fluid Sciences; and Division III, Systems and Design. The Heads and Associate Heads of the respective Divisions for the spring term were: Professors Ernest Rabinowicz and James Williams, Jr.; Bora Mikic and Ain A. Sonin; Warren Seering and David Gossard.

Accomplishments and Awards

Professor Ali Argon received the "Senior Scientist Award" from the Alexander von Humboldt Foundation.

Professor Mary Boyce received a National Science Foundation Presidential Young Investigator Award.

Professor William Durfee was appointed to the Brit and Alex d'Arbeloff Career Development Chair in Engineering Design for two years.

Professor Woodie Flowers was appointed as a School of Engineering Professor in Teaching Innovation for a period of two years.

Professor Ahmed Ghoniem received a Certificate of Appreciation from the American Institute of Aeronautics & Astronautics for his activities in professional education.

Professor Simone Hochgreb was appointed to the Lynde and Harry Bradley Foundation Career Development Chair for a period of two years.

Professor Harri Kytomaa received the Doherty Professorship in Ocean Utilization from the MIT Sea Grant College Program.

Professor John Lienhard V and his student Mr. X. Lin received the "1989 Best Paper Award" at the National Heat Transfer Conference for a paper titled "*Liquid Impingement Heat Transfer on a Uniform Flux Surface.*"

Professor Frank McClintock received the ASM Henry Marion Howe Medal for 1991 based upon a paper published in the *Metallurgical Transactions*. Professor McClintock was also elected to the National Academy of Engineering.

Professor Bora Mikic was elected a Fellow in the American Society of Mechanical Engineers.

Professor Thomas Sheridan was awarded an Honorary Doctorate by Delft University of Technology in the Netherlands.

Professor Joseph L. Smith, Jr. was appointed as Ford Professor of Engineering.

Promotions

Associate Professors Triantaphyllos Akylas and Anthony Patera were promoted to full professor effective July 1, 1991.

Assistant Professors Emanuel Sachs and John H. Lienhard V were promoted to associate professor, effective July 1, 1991.

Dr. Kenneth Salisbury was promoted to Principal Research Scientist, effective July 1, 1991.

John O'Brien was promoted to Department Financial Officer, effective January 15, 1991.

New Faculty

Professor Simone Hochgreb, who received her Ph.D. from Princeton University, was appointed as Assistant Professor in the Fluid/Thermal Sciences Division, in the spring term.

Resignations

Assistant Professor Steven Kim resigned effective June 30, 1991.

William J. Westcott, who served the department faithfully for 16 years as Administrative Officer, resigned to accept a position at Lincoln Laboratory.

Retirements

Professors Stephen Crandall and Frank McClintock retired effective June 30, 1991. Both will continue as emeritus professors and senior lecturers in the Department.

Deaths

Professor Emeritus August Rogowski passed away on March 13, 1991 at the age of 85. He was an active member of the Department for thirty years. He was director of the Sloan Automotive Laboratory and made seminal contributions to our understanding of the internal combustion engine.

A CLOSING NOTE

After serving as Department Head for nine years, I am resigning to accept a position as Associate Dean of the School of Engineering and on July 1, 1991, Professor Nam Suh will become the Head of the Mechanical Engineering Department. At this time I wish to express my sincere gratitude to the faculty and staff in the Department who have provided such strong support for and commitment to the Department. With the collective efforts of our faculty and staff, as well as those of the Department Visiting Committee, much has been accomplished in development of new educational and research programs, revitalization of teaching and research facilities and in developing sources of support in the form of career development chairs for junior faculty and fellowship support for graduate students.

I have very much appreciated the opportunity to serve the Department and work with such an outstanding group of faculty, staff and students.

DAVID N. WORMLEY

Department of Nuclear Engineering

INTRODUCTION

The Department of Nuclear Engineering (NED) continued to pursue its educational initiatives as outlined in the long-range plan of two years ago. The plan covers initiatives in the four main academic areas in the department: fission, fusion, radiation science and technology, and energy economics and policy. Three accomplishments in AY90-91 are noteworthy:

- The reformulation of the undergraduate program to a more unified curriculum covering the principles and applications of nuclear phenomena in the power industry and in the medical field.
- The formal establishment of the Advanced Nuclear Power Reactor Studies Program simultaneously with hosting the first MIT International Conference on the Next Generation of Nuclear Power Technology.
- The completion of the first phase of a plan to enhance the computational capabilities in the department by providing all faculty with workstations, some with visualization capabilities. Also, towards the end of the year a new Athena cluster was established in Building NW12.

In addition, the department stepped up its public educational role by hosting a televised conference on the future of nuclear power, organizing a short summer course on nuclear technology principles in addition to its continuation of the 25-year-old summer course on Nuclear Power Reactor Safety, and hosting a series of lectures on applications of nuclear phenomena in industry. The NED students, who celebrated the thirtieth anniversary of their chapter of the American Nuclear Society (ANS), significantly enlarged their High School Speakers Program and gave over 100 talks at high schools in New England.

A semiannual newsletter was published under the name *Know Nukes*, as the first department newsletter ever to be published by the NED.

ACADEMIC PROGRAM

An extensive review of the departmental undergraduate program has been completed. As a result, a new program has been adopted that will become effective with the students entering the department in the fall term 1991. The three tracks or options in the former program ("fission," "fusion," and "radiological sciences") have been replaced by two tracks in the revised program ("nuclear energy" and "radiation for medicine and industry"). Students in both tracks now take an introductory subject in reactor design, an introductory subject in radiation effects, and a design project subject in common. The new program has more unity, more breadth in nuclear engineering, and more design content.

During IAP 1991, two subjects were introduced for credit. Professor Sow-Hsin Chen's course, 22.922 Computer Modelling and Visualization in Engineering Science, offered three credits for completing six 1-1/2 hour lectures combined with laboratory work, and drew expertise from four areas of research represented by Professors Sidney Yip, Chen, Jacquelyn Yanch, and Eric McFarland. After a very successful trial offering during IAP 1990, Professor David Lanning incorporated into the curriculum a three-credit course entitled 22.921 Nuclear Power Plant Dynamics and Control. Professors Allan Henry and John Meyer and Dr. John Bernard assisted with this course.

During the academic year a new subject, 22.58 Seminar in Radiation Health Physics, was presented under the direction of Professor Yanch, assisted by Dr. Frank Masse and Professor Otto Harling. Topics pertinent to research and concern in the field of radiation health physics are presented as a weekly seminar series.

As part of a continuing initiative to upgrade the use of computers in NED courses, a large fraction of the NED faculty were provided Athena workstations in their offices. In addition, four faculty members were provided with networked workstations with visualization capabilities to explore the impact of visualization on teaching and research in nuclear engineering. A new cluster of Athena terminals was established in Building NW12.

STUDENT ENROLLMENT, HONORS, AND ACTIVITIES

Undergraduate Students

The undergraduate enrollment near the end of the school year was 12 (one sophomore, three juniors, and eight seniors). Four undergraduate degrees were awarded (two S.B.'s and two S.B./S.M.'s). Of the four degrees, three went to women (two S.B.'s and one S.B./S.M.).

Departmental honors were bestowed upon undergraduates Rodrigo Rubiano and Renee DuBord. Mr. Rubiano received the Irving Kaplan Award for the Outstanding Junior in Nuclear Engineering. Ms. DuBord was presented with the Roy Axford Award for the Outstanding Senior in Nuclear Engineering.

Graduate Students

During the academic year 1990-91, a total of 149 students were pursuing graduate work in the four areas of research offered by the department. Of this number, over 50 percent have successfully passed the Qualifying Examination. See the table below for more details. Also, the number of domestic students maintained a very slight edge over international students.

Discipline	Passed Qual Exam	Pre-Qualifying Exam; Other Degree Programs
Fission	28	34
Fusion	24	16
Radiation Sciences	22	16
Energy	5	4
Total Grad Students	79	70

A total of 48 advanced degrees were awarded by the department this past year. These included 21 doctoral, 1 engineer/master's, 24 master's, and 2 five-year bachelor/master's degrees.

The department's newly created "Outstanding Service Award" to recognize exceptional student contributions to the department, the Institute, and the nuclear engineering profession was presented to Michael Houts (Ph.D., June 1991). Mr. Houts was recognized for his numerous activities concerning the application of nuclear technology for space power and propulsion systems, which led to the initiation of the NED Space Program; and his service as a national co-chairman of the Space Exploration and Development Society; as well as for his outstanding work in organizing and participating in the High School Speakers Program of the ANS Student Branch.

To recognize their academic achievements, the department presented The Manson Benedict Fellowship for 1991-92 to Tony Hechanova, and The Theos Thompson Memorial Fellowship to Dong Wook Jerng for the fall semester 1991 and to Mickey Bhatia for the spring term 1992.

Bruce Hilton, a first-year graduate student, received the Sherman Knapp Scholarship for 1990-91, funded by Northeast Utilities. Other fellowship honors during the year included Jonathan Witter, the Space Grant Fellowship; Szu-Li Chang, the Exxon Fellowship; and David Cist, a fellowship from Schlumberger.

The Institute of Nuclear Power Operations granted the Department of Nuclear Engineering two fellowships for the 1990-91 academic year. One fellowship in the area of health physics was presented to Lou Doboie. The second fellowship for a student specializing in nuclear engineering was awarded to Phyllis Lovett.

Nine graduate students held Department of Energy (DOE) Fellowships for the academic year 1990-91. Kenneth Crosswait and Daniel Lo received Magnetic Fusion Energy Technology Fellowships. Nuclear Engineering and Health Physics Fellowships were awarded to Jill Broda, Vinh Dang, Tom DeLorey, Jess Gehin, Christine Martin, and Jerry Martin. William Hollaway was granted a fellowship in the area of Radioactive Waste Management. Mark Sautman, an incoming graduate student, will join this select group of DOE Fellows at NED in the fall.

In March, Kin Cheung (Ph.D., June 1990) received the annual TMS (The Metallurgical Society) award for outstanding student research for his thesis entitled, "An Atomistic Study of Fracture: The Brittle to Ductile Transition."

American Nuclear Society - MIT Student Branch

The MIT American Nuclear Society Student Branch serves as the focal point for social, athletic, professional, community service, and academic activities conducted by NED undergraduate and graduate students. The MIT ANS Student Branch was awarded the prestigious 1991 Samuel Glasstone Award as the Most Outstanding Student

Branch (among a total of 54 in North America) by the ANS national organization. Some of the activities over the past year by the ANS's 100 members, led by the Executive Committee, are briefly outlined here.

The ANS brings academic and professional speakers in from all over the world to speak at MIT on issues of nuclear science and engineering. This seminar series hosted 19 seminars on various topics from medicine to radioactive waste, with speakers from California to the Soviet Union. Total attendance at the seminars was over 600 students, faculty, and staff.

This was the most successful year in the history of the ANS High School Speakers Program (HSSP), a program run entirely by ANS students, which sends volunteer speakers out to high schools across New England to give talks on issues related to nuclear science, energy, and the environment. This past year 28 high schools were visited, and over 100 talks were presented to over 4000 students.

To celebrate its 30th Anniversary, the Student Branch designed, produced, and sold over 150 T-shirts commemorating the event. Proceeds from the T-shirt sales were used to fund some of its activities, including social and athletic programs.

The ANS developed and ran a Food Drive to Benefit the Homeless. Over 100 boxed and canned food items were collected and donated to a local shelter. The program was so successful and well received that it will be continued every semester.

Two successful Alumni Telethons to raise money for NED were planned, staffed and run by the ANS. The ANS Student Branch was the only organization to hold two telethons during the past year, one in the fall semester and one in the spring semester.

Alpha Nu Sigma Society - Massachusetts Beta Chapter

The Alpha Nu Sigma Society is the national honor society for nuclear science and engineering. Alpha Nu Sigma recognizes outstanding academic achievement by students in nuclear engineering by membership in the Society.

In conjunction with the Society's Annual Banquet, the MIT Chapter of the Alpha Nu Sigma Society inducted ten new members into the Society this past year, including one undergraduate and nine graduate students.

The MIT Chapter designed, produced, and distributed a 41-page "Student Guide to the Department of Nuclear Engineering at the Massachusetts Institute of Technology." They are currently readying a "Thesis Survival Manual" for distribution in the fall of 1991, and are in the process of writing a "Guide to Giving a Technical Presentation."

RESEARCH PROGRAM

Fission

The Advanced Nuclear Power Reactor Studies Program was formally announced at the beginning of the year, on the occasion of the First MIT Conference on the Next Generation of Nuclear Reactors. The program is directed by Professor Michael Golay. Work in the program aims at studying enhanced safety technology, improved regulatory process, and improved radioactive waste management. For safety enhancements, several faculty are investigating more passive designs as well as improved instrumentation and control of power reactors.

Professor Golay is investigating a methodology to simplify the power plant configuration. He and Professor Mujid Kazimi are also studying the containment system of advanced simplified boiling water reactors. In their project the ability to remove decay heat from the reactor to the environment via passive heat removal mechanisms is being investigated experimentally.

In the area of Modular High Temperature Reactors (MHTGR), work is now coordinated primarily by Professor Lawrence Lidsky, with help from Professor Lanning. Research includes the assessment of the passive safety features, the study of potential fission product plateout and release in the helium-cooled system, and the overall evaluation of the direct cycle (gas turbine) power plant design and operation. MIT was the host of an international topical meeting on the direct cycle power design in June.

Two aspects of decay heat removal are under investigation by Professors Neil Todreas and Michael Driscoll. In one project, two design approaches are being pursued to maximize passive decay heat removal under the

constraining assumption of unavailability of emergency liquid makeup. These are a solid matrix core in a pressure vessel and a system of solid matrix pressure tubes within a low pressure calandria tank. Their other project involves decay heat removal by air chimneys. Since rejection of decay heat to ambient air by natural convection is now a feature of many advanced reactor designs, an experimental model of a riser duct was run to develop correlations for heat transfer and friction behavior in this mixed convection region typical of modular high temperature gas reactor operation.

In the area of Advanced Instrumentation and Control (AIC), Professor Lanning served as the group coordinator. Other supervisory members of the group include Professors Meyer and Henry, and Dr. Bernard. AIC research involves the investigation of the use of state-of-the-art methods in reactor physics and thermal hydraulics to develop digital computer-based models for use in real time information and control systems. The objective is to reduce the possibility for human errors by improved information and fault-tolerant automation. Professor Lanning has also served as a coordinator for research in space nuclear power applications. This research involved the AIC group discussed above for application of the advanced control techniques on the MIT Reactor control system for the demonstration of automatic control. Proposals are in progress to continue the studies in space power systems as an interdepartmental research activity with Professors Jack Kerrebrock and Daniel Hastings of the Department of Aeronautics and Astronautics.

An International Program on Enhanced Nuclear Safety was developed by Professor Kent Hansen during this past year and will be administered by the Energy Laboratory. This program focuses on research to enhance the performance of existing plants via improved management and service/maintenance technology. Current sponsors include 11 domestic organizations as well as 13 international organizations.

Dose reduction studies for pressurized water reactors are being investigated by Professors Driscoll and Harling. In this regard, they have completed a major series of experiments in facilities utilizing the MIT research reactor to optimize the coolant chemistry (boron to lithium ratio). The Electric Power Research Institute (EPRI), the Empire State Electric Energy Research Corporation, and the Nuclear Power Engineering Test Center of Japan are sponsoring this research.

Professor Ronald Ballinger is also working with Professor Harling to investigate irradiation assisted stress corrosion cracking under conditions typical of boiling water reactors. They have designed and installed a special facility to perform the required tests inside the MIT Reactor. They are developing new instrumentation to help the operators of BWRs assess the stress corrosion potential of reactor components. This work is supported by EPRI, Tokyo Electric Power Company, GE, Hitachi, and Toshiba.

Professor Todreas continues his efforts in the area of thermal hydraulics and fluid flow. His projects include mixed convection flow recirculation in liquid metal reactor rod assemblies, and safety characteristics of operating light water reactors (LWR) of Western design. In the first, the flow behavior under boundary conditions of interest in the upper plenum and bundle sidewalls was experimentally investigated and modeled. The goal is to define the bounds of validity of one and two dimensional design methods describing these phenomena. In the second project, the safety characteristics of LWRs are described and compared in the areas of reactivity control, fuel, pressure control, reactor vessel materials, water level management, power sources, electric networks, emergency water makeup, post-accident heat removal, containment, and severe accident features.

In the area of reactor physics modelling, Professor Henry and his students have continued work on the development of nodal methods for the prediction of static and transient neutron behavior in reactors. In these methods, large, heterogeneous subregions (nodes) of the reactor are homogenized, and the transverse integrated fluxes within such regions are represented by polynomial expansions. Errors arising from the homogenization procedure or due to a low order of expansion are corrected by "discontinuity factors" determined from auxiliary calculations. The research program includes the following categories: development of new nodal codes; nodal synthesis; numerical testing of standard operating procedures; and faster running nodal codes.

Study in the area of reactor safety, reliability analysis and risk assessment is conducted by Professors Norman Rasmussen and Nathan Siu. A dynamic event tree methodology, needed to provide a framework for analyzing complex interactions between plant operators and the plant during an accident, was developed and applied to a steam generator tube rupture accident. Comparisons with conventional event tree analyses indicated that the

latter may be overly conservative. Insights concerning the effectiveness of plant emergency operating procedures were also developed. A simulation model treating the interactions among operating crew members during a nuclear plant accident was developed and benchmarked against the performances of real operating crews during training exercises. Three other projects underway involve the development of improved methods for Monte Carlo analysis of nuclear power plant accident sequences; the assessment of the risk impact associated with changes in a plant's service and maintenance program, and the application of risk assessment techniques towards the problem of accident precursors.

Research is in progress on new designs or potential modifications of the MIT research reactor. This research to date has been conducted only as the opportunity has arisen, such as in design classes and by self-supported students. The research information is to be used for decisions on the 1996 NRC license renewal required for the MIT Reactor. Work in this area is supervised jointly with Professors Lanning, Harling, Driscoll, and Lidsky, and Dr. Bernard.

Fusion

Fusion research is conducted primarily at the Plasma Fusion Center. NED faculty affiliated with this center include Professors Jeffrey Freidberg, Ian Hutchinson, Kazimi, Meyer, and Kim Molvig. Professor Freidberg's research interests include developing ultra fast reconstruction techniques for tokamak plasmas from magnetic data and developing new analytic techniques for investigating full wave ion cyclotron heating in inhomogeneous mirror geometries. He has also made basic contributions to the theory of Alfvén gap modes and has been a major contributor to the ITER Supercode being developed at Lawrence Livermore National Laboratory.

Professor Hutchinson heads the Alcator research project whose new tokamak experiment, Alcator C-Mod, will begin operation in the fall of 1991. This major experiment will provide vital physics and plasma engineering information for the design of burning fusion plasma experiments. The Alcator project currently supports ten NED students with research assistantships on projects ranging from building frozen hydrogen pellet injectors to developing fast feedback control systems for tokamaks.

Professor Kazimi's fusion technology efforts were directed at solutions to the material stability and heat removal needs of plasma facing components in steady state tokamak reactors. Professor Meyer also participates in studying several aspects of conceptual fusion power reactor divertor design. These aspects include planning for water experiments to confirm the viability of extremely high heat removal rates. They also include the study of a divertor composed of a flowing liquid metal.

Professor Molvig's research to develop algorithms in logic that yield hydrodynamic behavior has advanced. The ultimate scheme for massively parallel computers is close to being fully developed and ready for actual simulation.

Radiation Science and Technology

Research within the Radiation Science and Technology area is being conducted by Professors Gordon Brownell, Chen, Harling, McFarland, Yanch, and Yip. Professor Brownell's interest in the area of radiological sciences includes the development of advanced PET instruments; image processing for comparison of images; and Boron-10 assay on cellular level for microdosimetry. Biomedical applications of nuclear magnetic resonance (NMR) microscopy is a subject currently under investigation by Professor McFarland and staff from the Francis Bitter Magnet Lab and Massachusetts General Hospital. In the area of neutron tomography, Professors McFarland and Yip and Dr. Richard Lanza are collaborating on a study that uses the MIT Research Reactor as a thermal neutron source.

Based mostly on atomistic simulation, Professor Yip continued a fundamental study of the formation of amorphous states of matter by considering both liquid-glass transition (vitrification) and crystal-glass transition (amorphization). This work was supported by a National Science Foundation single investigator grant. He also concluded a study of the equilibrium structures of stepped surfaces on Si(001) which revealed the important effects of stress relaxation. An IBM single-investigator grant sponsored this study. In collaboration with Professor Ali Argon of Mechanical Engineering, Professor Yip continued a study of the nature of glass transition in polymers and the effects of structural relaxation using molecular dynamics simulation. Professor Yip and Professor S. Shyam Sunder of Civil Engineering continued their study of ice formation on various surfaces by means of molecular dynamics simulation. Professor Yip also collaborated with D. Wolf of Argonne National Laboratory on computer simulation studies of solid interfaces. A project to study the interfacial structure and mechanical properties of

inorganic matrix composites which combines atomistic simulation, electron microscopy, and vapor-deposition processing was initiated with funds from AFOSR.

The Department of Energy is sponsoring a research project to study boron neutron capture therapy for brain cancer. This project is a joint effort involving Professors Harling and Yanch and Dr. Robert Zamenhof and Dr. Hywel Madoc-Jones, both medical researchers at the Tufts New England Medical Center.

In the area of applied radiation physics, Professor Chen and his students have developed a new method of extracting the intermicellar structure factor for strongly interacting ionic micelles using SANS technique. Another study involves a technique for determining the Doppler frequency shifts in the scattered laser light from slowly moving particles. His other research program involves neutron spectrometry and molecular dynamics in solids and fluids.

Professor Yanch is involved in the development of new reconstruction techniques of medical images and of the optimum design of neutron sources that can be used for medical therapy with minimum effects on healthy tissue.

Energy Economics and Policy

Research in the area of energy economics and policy is conducted by Professor Richard Lester and Dr. Marvin Miller. Professor Lester is involved in a new program to continue the study of productivity and industrial performance begun by the MIT Commission on Industrial Productivity. Within MIT, the objective is to continue the effort begun by the Commission to promote greater awareness of critical productivity problems and to create an educational environment in which students can derive more inspiration from, and delve more deeply into, real-world problems of industrial performance as they pursue their studies in science, engineering, management, and the social sciences. Dr. Miller's research involves environmental impacts of energy production and use. Current research includes two studies of the energy policy implications of greenhouse warming and several studies on radioactive waste disposal.

FACULTY ACTIVITIES AND HONORS

Professor Chen directed a NATO Advanced Study Institute on "Structure and Dynamics of Supramolecular Aggregates and Strongly Interacting Colloids," that was held in Maratea, Italy, in June 1991.

Professor Freidberg received the American Nuclear Society Student Branch Outstanding Professor Award for the academic year 1990-91.

Professor Elias Gyftopoulos' textbook, *Thermodynamics: Foundations and Applications*, was published by Macmillan. It represents an entirely new approach to thermodynamics.

Professor Harling completed the publication of a volume on the results of an international workshop on neutron sources and neutron beams for neutron capture therapy, which he organized and which was held at MIT. He and the staff from the Nuclear Reactor Laboratory continued the successful program of offering seminars in nuclear technology to high school science teachers.

Professor Henry continued as a member of the Editorial Review Board of *Nuclear Science and Engineering* and is a member of the Program Committee of the Mathematics and Computation Division of the ANS.

Professor Hutchinson was appointed as associate editor of *Physics of Fluids B, Plasma Physics*.

Professor Kazimi was appointed chairman of the High Level Waste Tank Advisory Panel to review the safety of nuclear waste storage tanks of the DOE. He continues as member of the University of Chicago Special Committee to review the safety of the Integral Fast Reactor.

Professor Lanning continued as a member of the Safety Audit Committee of the Monticello Nuclear Generating Plant operated by Northern States Power Company. Professor Lanning serves as a co-chairman of the NSF-sponsored panel to assess European nuclear controls and instrumentation, which includes a literature search, two weeks of travel in Europe, a workshop in January, and a final report still in review.

Professor Lester has been a guest speaker throughout the year, both nationally and internationally. His speaking engagements include the House Ways and Means Committee of the US Congress, the American Council of Education, the National Academy of Engineering and Science, and lectures in Japan, France, Norway, and Italy.

Professor Meyer participated as a member of the Technical Program Group for the Savannah River Site Limits and Uncertainty Program.

At the Institute's Awards Convocation on May 1, Dr. Miller received The Graduate Student Council Teaching Award in the School of Engineering for 1990.

Professor Rasmussen is a member of the Oak Ridge National Laboratory Committee to Review the Cleanup of Radioactive Waste Storage Tanks. He is a member of the President's Commission on Catastrophic Nuclear Accidents which issued its report in the fall of 1990. He continues to serve on a committee that is reviewing the risk assessment of the Savannah River reactors. He also continues as a member of the Board of Trustees of Northeast Utilities, and is chairman of LNG Safety Committee, Cabot Corporation.

Professor Siu was promoted to Associate Professor. He participated as a member of the Technical Program Committee for the Nuclear Reactor Safety Division of the American Nuclear Society. He organized and chaired a special session at the inaugural Society for Risk Analysis meeting on Probabilistic Safety Assessment and Management.

Professor Todreas was named a member of the National Academy of Sciences committee, Nuclear Power: Technical and Institutional Options for the Future, a report to be issued summer 1991.

Professor Yip (and D. Wolf of ANL) edited a two-part series on the theme of "interfaces" in MRS (Materials Research Society) Bulletin, September and October issues, 1990. Professor Yip gave an invited lecture at a Taniguchi Symposium on Molecular Dynamics Simulation, Kashikojima, Japan, in November 1990. He also gave several lectures on molecular simulation in materials research to Japanese corporate research laboratories (Nippon Steel, Showa-Deuko, Kobe Steel). In June, he was invited to present a series of five lectures on Radiation Science and Technology in the 1990's at the Research Science Institute in Washington, DC, a summer program for gifted high-school students conducted by the Center for Excellence in Education.

MUJID S. KAZIMI

Department of Ocean Engineering

INTRODUCTION

Several years ago, the Department of Ocean Engineering defined its mission in terms of three areas of technology:

- naval systems and operations (especially submarines);
- deep-sea technology;
- technology for ocean science.

These areas remain the focus of the Department, although there have been some changes in emphasis. For example, naval ship systems are more and more constrained by the expense of building them; thus the Department, in both its research and teaching programs, is placing more emphasis on *design for production*, *technologies involved in fabrication*, and *the organization and management of manufacturing operations* (see *GRADUATE EDUCATION, SHORT COURSES, RESEARCH*). *Deep-sea technology* now encompasses a broader scope of activities than ever, notably the development of autonomous underwater vehicles and other systems for acquiring data in the ocean, both of which also serve the ocean science community well (see *STUDENT PROJECTS, RESEARCH*). Acquisition of data and modeling of physical systems for understanding global climate change is becoming an ever more important objective of the Department.

The Department's traditional areas are also progressing well. The offshore industry is demonstrating more interest than ever in research and students (see *RESEARCH*). New support is being received from shipping companies concerned with high costs, and the performance of ships generally continues to attract attention.

Overall, research funding has grown by about 30% per year for several years. One consequence of this is evident in the section *FACULTY AND RESEARCH STAFF*: The Department has hired seven new research engineers in a one-year period. (There were none just five years ago.)

The Department has started a new initiative to redefine its undergraduate curriculum in ocean engineering (see *UNDERGRADUATE EDUCATION*).

The Corporation Visiting Committee for Ocean Engineering held its biannual meeting May 1-2, 1991, preceded by a visit to the Woods Hole Oceanographic Institution (WHOI), which plays an increasingly important role in the Department's teaching and research programs.

UNDERGRADUATE EDUCATION

New Subjects in Ocean Science and Technology: A new two-term sequence of subjects, 13.010/011 Introduction to Ocean Science and Technology I/II, was announced last year. The full sequence was taught this year, the first part in the fall term by Professor Jerome H. Milgram, Associate Professor Henrik Schmidt, and Dr. Wayne R. Geyer (WHOI), and the second part in the spring term by Professor Milgram. Both were partially successful, although in quite different ways.

The first subject includes three modules, (i) oceanography, (ii) acoustics, and (iii) waves and dynamics. The level at which the material was presented more nearly matched that of the students than it did in the previous year, and the amount of material was reduced somewhat. We were less ambitious, and, as a result, the students enjoyed it more.

The high point of the second subject was supposed to be an at-sea experiment. Indeed, it was planned that way until the time arrived for the experiment. After one attempt was canceled because of rough weather and a second attempt *should* have been canceled for the same reason, the design of the experiment was modified so that it could be done on the Charles River. With the cooperation of the Harvard Sailing Club, which allowed the use of its dock, the experiment was finally carried out in just one afternoon. After all the frustrations, it was a good ending. In fact, the data collected are nearly of archival quality, and they suggest that there is an error in a standard formula used by oceanographers to predict the rate at which short wind-generated waves develop. The students had the satisfaction of knowing they had produced some new knowledge.

The sequence will be repeated next year, although enrollment in both subjects was disappointing (11 in the fall term, six in the spring term). In retrospect, however, it is clear that the size of the class in the spring term must be restricted if an at-sea (or at least an out-of-doors) experiment is to be conducted.

Study of the Ocean Engineering Curriculum: Throughout the fall term, a committee chaired by Professor Ira Dyer deliberated on the future of the Department's bachelor's degree program in ocean engineering. The committee's report focused on three items:

- The Department as a whole must develop a consensus on the definition of *ocean engineering*, at least as it applies to the Department's undergraduate curriculum. (The committee suggested how to go about this, but it did not indicate what the consensus should be.)
- There is an immediate need for an undergraduate subject on physical oceanography for engineers, regardless of what general consensus may be reached on the curriculum.
- The committee strongly recommended that renewed efforts be made to build up the undergraduate enrollment.

During the coming year, the Department will be working on the implementation of these recommendations.

GRADUATE EDUCATION

Manufacturing: Over a period of many years, the Department of Ocean Engineering has made many contributions to the technology of manufacturing in the marine field. The longest-running program in this area is Professor Koichi Masubuchi's research on welding, which has been widely recognized in the United States and abroad. In recent years, the Department has moved into several other areas of fabrication technology as well, such as (a) new computer-based concepts that focus on designing for manufacturability and (b) novel forming techniques. (See *RESEARCH* below.)

Now more and more attention is being given to questions involving the management and organization of manufacturing, as well as the design/fabrication interface, and the new knowledge generated is being moved rapidly into the Department's teaching program. Professor Ernst G. Frankel's three new subjects are examples of this development: 13.61 Project Management, 13.65 Management of Technological Change, and 13.631 Management of Manufacturing. He has also written two books on these subjects, which were published this year (see *BOOKS* below). In the fall, Professor Frankel taught a condensed version of the project-management subject, which attracted the largest enrollment of any subject in the Department (69), over half the students coming from the Sloan School of Management and the Management of Technology Program. For the last two years, under the leadership of Professor Henry S. Marcus, the capstone project in Course XIII-B (Ocean Systems Management), has focused on shipbuilding, attracting students from Course XIII-A (Naval Construction and Engineering) as well as from Course XIII-B.

The predominance of naval programs in US shipbuilding and the escalating costs of shipbuilding motivated the introduction of a manufacturing component into Course XIII-A two years ago. Students are required to take at least one subject in the area, and the area can be selected for concentration as well. Professor Randolph M. Brooks, in his subjects on ship design, now provides extensive coverage of producibility topics and their relationship to design. As noted below (see *SHORT COURSES*), a new one-week course on ship production will be offered this summer, primarily for the benefit of the naval officers in Course XIII-A. The Navy has helped to support these developments through the funding of a five-year faculty chair of ship acquisition, to which Professor Marcus has been appointed (see *FACULTY AND RESEARCH STAFF*).

Oceanographic Engineering for US Navy Officers: In addition to its long-standing program in Naval Construction and Engineering (Course XIII-A), which was established in 1901, the Department has become the focus of a much newer program in oceanographic engineering for US Navy officers. Students in this program go through the normal, rigorous admission process for the MIT/WHOI Joint Program, and their study/research programs parallel those of nonmilitary students, although they generally terminate their studies after just two years with master's degrees. For several years, enrollment has been steady at a level of 12 to 15.

SHORT COURSES

Professional Summer Program: In collaboration with the Draper Laboratory, the Department continues to offer its Professional Summer Program, eight weeks of short courses that complement the regular program of Course XIII-A, *Naval Construction and Engineering*. Last year, Professor B. F. Tibbitts completely reorganized the summer program, and the new version was first offered this year (summer 1990). It now consists of two groups of one- or two-week courses:

Submarines

- Observables, Survivability, and Control
- Design Trends (two weeks)
- Combat Systems

Surface Ships

- Combat System Engineering (two weeks)
- Survivability and Observables
- Combat System Design Integration

This year, the Department has planned an additional one-week course, *Advanced Ship Production*, which will first be given this summer. It will be taught by Professor Howard M. Bunch of The University of Michigan, who has also been a Lecturer at MIT for several years.

STUDENT PROJECTS

Autonomous Underwater Vehicles (AUVs): Students (many of them undergraduates) working in the MIT Sea Grant College Program designed and built an autonomous underwater vehicle, *Sea Squirt*, which is being deployed in the Charles River and Boston Harbor this year. The team is now concentrating on intelligent mission planning and navigation, and it will soon start working on two more vehicles, both considerably more advanced. One will be designed to operate in the Arctic (under the ice) and the other to operate at depths as great as 6,000 meters.

This project is directed by Professor Chryssostomos Chryssostomidis; it was the inspiration for his proposal that won him a new chair in innovative teaching (see *FACULTY CHAIRS* below).

Course XIII-A Design Projects: The principal objective of Course XIII-A, *Naval Construction and Engineering*, is to prepare students (mostly naval officers) to lead in the design and construction of ship systems. Thus the year-long ship-design project is a focus of the program. This year, students undertook major projects designing

- a large-depth autonomous underwater vehicle with glass-sphere pressure hulls and a radio-isotope thermoelectric generator
- an affordable contingency and limited-objective-warfare submarine
- a cargo ship that can be converted rapidly between commercial container service and military-sealift roll-on/roll-off service
- a coastal patrol vehicle

These projects were supervised by Professors Brooks and Chryssostomidis and Associate Professor Richard C. Celotto.

Rowing: The Department, in cooperation with the MIT Sea Grant College Program, continues to sponsor an investigation of rowing by a group of undergraduate and graduate students. This has involved an experimental study of the hydrodynamics of oar blades during the rowing stroke and computer modeling of the process. The next phase of the study will focus on the development of improved oar blades and instrumentation to assist in the testing of oars and rowing techniques. The work is supported, in part, by the United States Olympic Committee and the MIT Sea Grant College Program. Participating faculty members include Professors A. Douglas Carmichael and Justin E. Kerwin and Associate Professors Paul D. Sclavounos and Dick K.-P. Yue.

ROBERT BRUCE WALLACE LECTURE AND PRIZE

The Ninth Robert Bruce Wallace Lecture was delivered on October 24, 1990, by Susan M. Lee Bales, Science Advisor to the Chief of Naval Operations. Her topic was "The New Road: Ocean and Naval Engineering in the 1990s." Ms. Bales described changes in the nation's requirements in science and technology, especially those that relate to the nation as a maritime power. She presented a generic model for linking postulated future naval mission requirements with ship design and modernization technology and with the ocean sciences.

On the same occasion, the Robert Bruce Wallace Academic Prize was formally presented to Rebecca A. Zavistoski, the first junior ever to win the Prize.

FACULTY CHAIRS

Two endowed chairs were awarded to members of the Ocean Engineering faculty this year:

Professor Arthur B. Baggeroer was named Ford Professor of Engineering in recognition of his achievements in signal processing and acoustic wave modeling. Professor Baggeroer has provided intellectual and organizational leadership in several areas of research, including Arctic acoustics, ocean-bottom reverberation, acoustic telemetry in the ocean, trans-global sound transmission to determine the rate of global warming, and structural acoustics. He recently served for five years as Director of the MIT/WHOI Joint Program.

Professor Chryssostomos Chryssostomidis was named to one of two new chairs in Teaching Innovation in the School of Engineering. The award was made on the basis of his proposal to conduct an experiment in the education of undergraduates in the design of systems requiring a multi-year team effort. The experiment will focus on the design of autonomous underwater vehicles, an area in which Professor Chryssostomidis is already supervising a small group of students. (See *STUDENT PROJECTS*.)

These awards bring to five the number of Ocean Engineering faculty members holding endowed chairs. The others are Ira Dyer, Weber-Shaughness Professor of Ocean Engineering, Koichi Masubuchi, Kawasaki Professor of Engineering, and Jerome H. Milgram, William I. Koch Professor of Engineering.

FACILITIES

The **Marine Computation and Instrumentation Laboratory**, directed by Professor Milgram, moved to Room 1-225 after 19 years in space that was on loan from the Mechanical Engineering Department. Professor Milgram continues to be involved in an ever widening scope of field experiments, for which this laboratory is the instrumentation-development site and the staging area. It is also the location of his America's Cup activities (see *RESEARCH*).

Renovation and modernization of the **Ocean Engineering Test Facility** (formerly the towing tank) is continuing under the direction of Professor Michael S. Triantafyllou. A new carriage motor, an automatic gear system, and a new data-acquisition cable have been installed. The new carriage drive is feedback controlled, so that high-accuracy continuously variable speeds can easily be set and achieved. New software for the wavemaker will soon be installed, allowing digital creation of input signals.

BOOKS

The following books by Professor Ernst G. Frankel were published during the year:

Management of Technological Change, John Wiley Interscience, New York

Project Management in Engineering Services and Development, Butterworth Scientific, London

RESEARCH

Power Plants for Unmanned Underwater Vehicles (UUVs): Professor Carmichael has been conducting a study of possible power plants for a UUV developed by the Draper Laboratory. His proposal was to replace the batteries in the existing vehicle with fuel cells or other compact energy sources for future designs. Professor Carmichael has been concentrating on an experimental investigation of an aluminum/oxygen cell, a system that is very compact but not completely understood.

Sandwich Structures for Submersible Hulls: Conventional pressure hulls cannot be designed for pressures exceeding about 600 atmospheres (20,000 ft) unless they are provided with some form of external buoyancy system. One way to get around this limitation is to use an unconventional hull, and so Professor Chryssostomidis and Dr. Nikiforos Papadakis, Research Engineer, have been investigating the use of a novel sandwich structure that offers greatly improved strength/weight performance. The particular kind of sandwich structure they are studying is an attractive candidate for this function largely because of recent advances in fabrication (joining) technologies; Professor Thomas W. Eagar, Materials Science and Engineering Department, is providing guidance in this area. This sandwich structure also offers the possibility of greatly reducing radiated noise.

Low-Tension Cable Systems: Although cables are commonly used as structural elements under tension, there are numerous situations in which they may have very small or even zero tension, for example, in the deployment of fixed hydrophone arrays in the ocean, during the towing of arrays, and when used as tethers for unmanned underwater vehicles. Very little is known, however, about the dynamic behavior of low-tension cables. Professor Triantafyllou is addressing this problem by developing an analysis and computer code for the case of low-tension cables subjected to impulsive motions. Previous methods of analysis failed whenever the tension vanished, because the governing equations became singular. By reverting to the non-extensible form of the governing equations and including the (small) bending stiffness, Professor Triantafyllou has been able to remove the singularity and obtain uniformly valid solutions.

Arctic Underwater Acoustics: This program, which appeared last year to be winding down, is now taking on new life, at least partly because of some recent contributions by Professor Dyer and his students:

- a taxonomy for transient-event signatures associated with fracture;
- procedures for locating events in space and time with hydrophone arrays;
- first-order extraction of ice forces and ice fracture moments, which are homologous attributes of the ice, independent of details of environmental forcing;
- summaries of the number spectral density of ice fracture events, which is dependent upon local environmental forcing and therefore sets the average aggregated noise (ambient level);
- a physical connection between ice-source mechanics and earthquake-source mechanics, in which ice observations can be thought of as a "laboratory" for earthquakes, and for which earthquake seismology theory and practice can guide further development of ice fracture mechanics;
- identification of surface gravity waves as the main environmental force governing aggregated noise in the marginal ice zone, with ice concentration as a modulating parameter.

Measurements to Determine the Rate of Global Warming: Although there exists a near-consensus that the Earth is warming, there is no agreement whatever on what the rate of warming is. To settle this, an appropriate measure is needed of the mean worldwide temperature, averaged in time over periods of at least a year. Atmospheric temperatures fluctuate so much in time and space that obtaining such a measure is near to impossible. Ocean temperatures (below a thin surface layer), on the other hand, are very steady. So an experiment was proposed to measure the rate of change in the transit time of a sound wave passing through a large part of the ocean. Since the speed of sound in the ocean depends strongly on water temperature, changes in transit time could then be correlated to temperature changes.

A year ago, the most immediate question about this proposal was whether sound waves could be transmitted and detected over sufficiently long paths to achieve an acceptable spatial average of temperature change. This year, the first such experiment was conducted. Professor Baggeroer and colleagues from several other institutions used receiver arrays on both coasts of the United States to measure the time of transit of sound waves generated in the Southern Indian Ocean. Through the use of advanced signal processing techniques, they were successful in determining precise arrival

times of sound waves that had been traveling for several hours. This does not provide any information on how rapidly the Earth is warming, but it does suggest that a means may soon be available to answer this important question.

Ocean-Bottom Reverberation: The experimentally observed reverberation levels at low frequencies in ocean basins cannot be explained by acoustic theory alone. Elastic effects from the basin boundaries are suspected to be the cause of discrepancies in predictions, although this cannot be proven yet. To help resolve this uncertainty, Professor Schmidt, in collaboration with experimentalists both inside and outside of the Department, is extending his propagation model, which is the established standard in the underwater acoustics community. He is developing a hybrid boundary-element approach to the simulation of propagation and reverberation in a stratified ocean with elastic objects. This approach will be applied to the analysis of scattering processes under Arctic ice, bottom reverberation, and scattering and radiation by structures with facets such as stiffeners.

Synthetic Aperture Sonar: The resolution of detection and imaging systems depends largely on the size of the receiver with respect to the length of the waves that are used. For this reason, precise imaging in the ocean with sound waves requires immense hydrophone arrays if conventional technology is used. Professors Milgram and Schmidt and a student have been studying the feasibility of using systems analogous to those of synthetic aperture radar (SAR) for this purpose. A synthetic aperture is created by taking measurements at several locations as the receiving instrument moves along a track. Acousticians have generally assumed that coherence defects in the acoustic medium (the ocean) would prohibit such a development. The MIT group has shown, however, that the major difficulty is the low speed of sound, compared to the speed of the electromagnetic waves used in SAR systems. Synthetic aperture acoustics should be feasible for certain ocean conditions, although much development remains to be done.

Multimodal-System Equipment Management: One of the most important problems in liner shipping is effective container management; ownership, leasing, and relocation of containers may account for 30% of the costs of container shipping companies. Professor Frankel and his students have developed a deterministic empty-container reassignment/relocation model, which minimizes the product of the number and distance (and thus the cost) of empty-container moves while satisfying all container demands. The model includes the impact of adding or subtracting containers from outside the region by leasing, return of leased containers, or transfer of empties between regions. When tested against data on past empty-container relocations and assignments, the model was shown to give improvements of over 10% in relocation and container-inventory costs, with no reduction in customer-demand satisfaction. The next phase of this research will be the development of a stochastic demand/supply model for containers.

Optimum Cargo Booking: Professor Frankel has produced a stochastic conditional decision model for maximizing the total freight revenues obtained from a voyage. Freight rates for containerized cargo depend mainly on their value. Cargo bookings are usually made randomly. The model uses strategies that, for a multiport pair voyage, maximizes the expected value of the product of the total number of containers carried and their respective freight rate. Cargo demands or bookings for different port pairs are represented by time-varying probability distributions. The model, in tests against past decision methods, has been shown to improve voyage revenues by 10 to 16%; it accomplishes this through a more effective allocation of cargo space.

Environment-Friendly Tankers: As a *pro bono* contribution to the work of a National Academy of Sciences/National Research Council panel (chaired by Professor Marcus), Professor Tomasz Wierzbicki carried out a damage analysis of ship groundings. He was able to determine the vertical, transverse, and longitudinal extent of damage of a traditional (MARPOL) supertanker for a particular ground-impact situation. Subsequently, he and Visiting Professor Dag Kavlie organized an international team from the United States and Norway to undertake a project, *Design, Construction, and Operation of Spill-Free Tankers*. The Norwegian side is being funded, but US sources of funding have not yet been identified. In the meantime, two of Professor Wierzbicki's students have completed master's theses in this area, and yet another has started.

Praxiteles, a Geometric Modeling System for Sculptured Curves and Surfaces: Professor Chryssostomidis and Associate Professor Nicholas M. Patrikalakis this year issued the third release of the computer program *Praxiteles*. Developed for the US Navy, it makes possible accurate data exchange, high-accuracy shape approximation, advanced shape interrogation, and automated inspection. It has been provided to the David Taylor Research Center, the Applied Research Laboratory of the Pennsylvania State University, the Oakridge National Laboratory, and Westinghouse to facilitate the accurate and efficient exchange of data among different computer-aided design (CAD) systems used in the design, manufacturing, and inspection of marine propellers.

Simulation of Manufacturing Processes of Thin Stiffened Shells: As *design for manufacturing* receives more and more attention from US industry, it becomes increasingly important to be able to create computer simulations of the processes of fabrication. In a joint program with the Department of Materials Science and Engineering and the Department of Mechanical Engineering, the Department has been developing fundamental concepts and methods that are needed for this purpose, especially for application to processes of forming thin stiffened shells, which predominate in most marine structures.

As part of this program, Professor Patrikalakis has extended his research on the *medial-axis transform*, which makes possible the automatic extraction of design features from a geometric model. It is valuable, for example, in the automated idealization and discretization of structures for analysis with the finite-element method (FEM). It allows the extraction of such properties as camber surface, thickness, *etc.*, of a marine propeller from the equations defining its surface, and it provides a means of idealizing such geometries for preliminary analysis and for verifying manufacturing tolerances during inspection.

Distortion and Residual Stresses in Welded Structures: Professor Masubuchi is undertaking a collaboration with the E. O. Paton Electric Welding Institute in Kiev, USSR, which is by far the largest such organization in the world (10,000 employees). The objective will be to combine Soviet and Western knowledge of residual stresses and distortion in welding fabrication and to prepare a comprehensive summary. The American Welding Society has expressed interest in supporting the effort and in publishing the document that will result from the MIT/Paton joint project.

Overmatched vs. Undermatched Welds: Whenever high-strength steels are used in fabrication, it is very difficult to (a) produce a weld metal that matches the base metal in both strength and fracture toughness and (b) prevent weld cracking without very high preheating temperatures. The US Navy has generally required that the weld metal have at least as much strength as the base metal (*overmatching* in strength), while it accepts less fracture toughness in the weld metal (*undermatching*); this approach requires much preheating, and it cannot be used at all with very-high-strength steels such as HY-130. If welds are accepted that are somewhat undermatched in strength, lower preheat temperatures can be used.

Professor Masubuchi and a student have addressed one aspect of these questions: It is well-known that, in a butt joint between heavy plates of high-strength steel, weld-metal cracks occur most frequently during the first pass. In fact, it may be advisable on the first pass to use a weld metal with relatively low strength but high crack resistance. Then a crack-free first pass can be made with relatively low preheating temperatures. Experiments in Professor Masubuchi's laboratory have confirmed this idea.

Forming Large Double-Curvature Shells by Local Rolling: Forming large plates into the complex shapes that are typical of marine structures is a difficult process, especially when only one of a kind is required. In US practice, it is also a process that generally requires a large investment in shipyard equipment. Professor Wierzbicki has proposed an alternative approach, using a narrow roller in multiple passes that are computer-controlled to give the prescribed curvature. Extensive simulations have been made on the MIT supercomputer to demonstrate the feasibility of the new process, which would greatly reduce the need for heavy rolling equipment.

Propulsors: Very detailed hydrodynamic analyses are required for the design of modern marine propulsors, which may involve extreme blade geometries, multiple stages, ducts, high lift coefficients (resulting from lower rotation speeds), and cyclically varying blade pitch. Some designs require knowledge of unsteady forces at reduced frequencies that are much greater than those ever studied in aerodynamics.

To meet such needs, Professor Kerwin, his research staff, and students have taken a variety of approaches. For example, Dr. Spyridon Kinnas, Research Engineer, and two post-doctoral associates, Dr. Ching-Yeh Hsin and Dr. David P. Keenan, have developed a boundary-element method that accounts for the thickness-loading interactions on a wing or propeller of arbitrary shape, allowing the designer to control thickness effects on loading. In unsteady-flow problems, they have been focusing especially on very-high-frequency harmonics; they have found cases, for example, in which the 25th-harmonic torque is significant. Other areas of ongoing activity are unsteady multi-stage ducted propulsors and the propulsive-performance and maneuvering-force characteristics of a ducted propulsor with cyclically varying pitch.

Sailing Vessels: Data obtained with the sail dynamometer developed by Professor Milgram have proven invaluable in improving the performance of offshore racing vessels. As noted last year, the dynamometer, which is actually an entire sailboat with appropriate instrumentation to measure loads between the hull and the sail system, was destroyed in a

boatyard accident, but it is now being rebuilt. The new sailing-yacht technology developed by Professor Milgram is currently being used in the design of America's Cup class vessels.

Vortex/Free-Surface Interactions: Since the analysis of free-surface waves has generally been feasible only on the basis of ideal-fluid, irrotational-flow models, little research has been devoted to understanding the interactions between vorticity and a free surface. Recent interest in ship-track detection has, however, made this an important problem and has attracted widespread interest to it, notwithstanding its inherent difficulty. Professor Yue first turned to this subject using methods that he had developed for fully nonlinear body/wave computations. He incorporated vorticity by assuming that it exists in the form of discrete sheets, as is usually done, for example, in propulsor analyses. In the last two years, however, Professor Yue has taken up the more difficult problem of using a true viscous-fluid model. With a colleague, Dr. Douglas G. Dommermuth of SAIC, San Diego, he has produced convergent simulations of vortex rings and unstable vortex-tube couples rising toward the free surface. Some fundamental new processes and phenomena have been identified, quantified, and compared to the case of a rigid free-slip or no-slip top boundary.

Joint Industry Project (JIP) on Platform Dynamics: The JIP, which had been initiated with a group of companies in the offshore industry by Professor J. Nicholas Newman and Professors Sclavounos and Yue, concluded a year ago. The program was immediately extended with a wider base of participating companies, this time under the direction of Professor Newman alone. Most of the technical activity was devoted to the development of a "complete" second-order solution for the hydrodynamic loads on a floating platform. Of particular importance was the computation of unsteady second-order forces on a fixed body, since tension-leg platforms (TLPs) experience substantial vertical forces that arise from the "microseism" effect of the second-harmonic pressure, which decays very slowly with depth.

Statistical Dynamics of Floating Structures: Real ocean waves are random processes and can only be described statistically. Thus the loads they impose on platforms, as well as the resulting motions, must also be described statistically. The methodology for doing this in predominantly linear problems has long been established, but the most critical loads and motions for moored floating platforms arise from second-order effects, for which the statistics have generally been handled by heuristic methods. Professor Sclavounos has undertaken to remove this deficiency, and he has already demonstrated one remarkable fact, which he expects will be significant in the design of deep-water tension-leg platforms: The solution of the third-order hydrodynamic problem may contribute a high-frequency load larger than that obtained from the solution of the second-order problem.

FACULTY AND RESEARCH STAFF

Steven Abrams was appointed Research Engineer as of December 1, 1990.

Professor Arthur B. Baggeroer was named Ford Professor of Engineering (see *FACULTY CHAIRS* above).

For half the year, Professor Baggeroer served as Acting Director of the MIT/WHOI Joint Program, a position that he had previously held for five years.

CAPT Randolph M. Brooks, USN, joined the faculty in September for a three-year appointment as Professor of Naval Construction and Engineering. Before that, he had been assigned most recently to the Mare Island Naval Shipyard, where he served as Deputy Shipyard Commander for Ocean Engineering and managed a conversion project of magnitude comparable to the building of a major new ship.

Professor Brooks received the Presidential Award of Gold Star in lieu of a third award of the Meritorious Service Medal for his accomplishments at the Mare Island Naval Shipyard prior to joining the MIT faculty.

Professor A. Douglas Carmichael continues to serve as Director of the MITES (Minority Introduction to Engineering and Science) Program in the MIT School of Engineering. He is also Chairman of the MIT Faculty Instructional Resource Program (FIRP).

Associate Professor Richard C. Celotto, CDR, USN, has been assigned collateral duty at the Naval Sea Systems Command, with responsibility for coordinating academic inputs to the Navy's new initiatives to accelerate the development of new ship concepts and encourage the development and use of new technologies in ship design and construction.

Professor Chryssostomos Chryssostomidis was named to a new Chair of Teaching Innovation in the School of Engineering (see *FACULTY CHAIRS* above). He continues to serve as Director of the MIT Sea Grant College Program.

Professor Ira Dyer was appointed to (i) the Membership Policy Committee, National Academy of Engineering, (ii) the External Research Review Board, Naval Research Laboratory, and (iii) the Review Committee, Hydrodynamics and Hydroacoustics Technology Center, David Taylor Research Center.

D. Noah Eckhouse was appointed Research Specialist on November 14, 1990.

Professor Leopold B. Felsen of the New York Polytechnic University was a Visiting Professor, working primarily in the area of structural acoustics. Professor Felsen is a University Professor and former Dean of Engineering at New York Poly. During the year, he was awarded the Heinrich Hertz Medal by the Institute of Electrical and Electronics Engineers. Professor Felsen was elected to the National Academy of Engineering in 1977.

Professor Ernst G. Frankel has been elected Honorary Member of the National Academy of Science and Engineering of Argentina, Honorary Member of the Society of Naval Architects and Marine Engineers of Singapore, and Honorary Life Member of the Institute of Marine Engineers (UK). He continues to hold appointments as (i) US Representative to the Technical Committee of the Permanent International Association of Navigation Congresses (PIANC), (ii) Advisor to the Rector of the World Maritime University, Malmo, Sweden, and (iii) Senior Advisor to the Secretary General, International Maritime Organization, United Nations.

Professor Frankel was on sabbatical leave during the spring term, doing research at the Brookings Institution.

Dr. J. Robert Fricke has accepted an offer of appointment as assistant professor, effective July 1, 1991. Dr. Fricke recently completed doctoral studies in the MIT/WHOI Joint Program in Oceanographic Engineering with a thesis, "Acoustic scattering from elastic ice: A finite difference solution." Before undertaking doctoral studies, he had worked for eight years at Atlantic Richfield Co., during the last five years of which he was Director of Marine Systems and Standards. Dr. Fricke will collaborate primarily with the Department's ocean-acoustics group.

Dr. Yueping Guo was appointed Research Engineer, to be effective July 1, 1991.

Professor Dag Kavlie was a Visiting Professor for the year. When he came to MIT a year ago, he had just completed two terms (six years) as Rector of the Norwegian Technical University in Trondheim. This year, he lectured in two subjects on the structural design of ships and collaborated with Professor Wierzbicki in a project on the mechanics of ship groundings. During the year, he gave the keynote speech at a meeting in Leningrad of rectors of European universities.

Dr. David P. Keenan was appointed Research Engineer, to be effective July 1, 1991. He had been appointed Lecturer during the year.

Professor Justin E. Kerwin received the Graduate Student Council Teaching Award at the Institute Awards Convocation in May 1990.

Associate Professor Judith T. Kildow was on leave for most of the year to help develop an international environment program at Tufts University. There she created and directed the Faculty Research Colloquium on Environmental Problems and participated in other related activities.

Professor Kildow was appointed to the Technical Advisory Committees for the Massachusetts Secretary of Environmental Affairs and for the Massachusetts Bays Research Program. She continues to serve on the Marine Board of the National Academy of Science/National Research Council.

Dr. Chang-Ho Lee was appointed Research Engineer on July 1, 1990.

Associate Professor Henry S. Marcus was named NAVSEA Professor of Ship Acquisition; this term chair is being made possible under a five-year grant from the Naval Sea Systems Command and the Office of Naval Research.

Professor Marcus was chairman of a panel of the Marine Board of the National Academy of Sciences/National Research Council that was charged with studying ways of preventing accidents like that of the EXXON VALDEZ. The panel recently finished its report, *Tanker Oil Spills: Prevention by Design*. The Oil Pollution Act of 1990 requires the Secretary of Transportation to analyze this report in the formulation of new policies on tanker design.

Professor Koichi Masubuchi was elected a Fellow of the American Welding Society (AWS). This was an unusual distinction, since it was the first time the AWS had ever bestowed this honor on anyone, and only 13 persons were selected.

Professor Masubuchi is the MIT Coordinator for the Graduate Student Exchange Program with the University of Tokyo.

Charles Mazel was appointed Research Engineer, to be effective July 1, 1991.

Dr. Dimitris Nakos was appointed Research Engineer, to be effective July 1, 1991.

Dr. Nikiforos Papadakis was appointed Research Engineer as of December 1, 1990.

Associate Professor Nicholas M. Patrikalakis was awarded tenure, based on his outstanding accomplishments in geometrical modeling of sculptured objects. Professor Patrikalakis started working in this area about five years ago, after a major change of field (from the structural dynamics of marine risers).

Professor Patrikalakis was the program chairman and local organizer of an international conference at MIT in June, *Computer-Graphics International: Visualization of Physical Phenomena*. The conference proceedings, edited by Professor Patrikalakis, are being published by Springer Verlag.

Associate Professor Henrik Schmidt was elected a Fellow of the Acoustical Society of America, primarily for his accomplishment in developing a new methodology for the computer modeling of sound propagation through complex layered media. Professor Schmidt has also been named chairman of the Technical Committee on Underwater Acoustics of the Acoustical Society of America.

Professor Barrick F. Tibbitts resigned as Professor of Naval Construction and Engineering in August to take a position in private industry. He had been a faculty member since 1987, while also serving as a captain in the US Navy.

Professor Michael S. Triantafyllou was appointed Visiting Investigator at the Woods Hole Oceanographic Institution.

Professor J. Kim Vandiver has just started (June 15, 1990) a two-year term as Chairman of the MIT Faculty, following his appointment a year ago as Chairman Elect. During much of the past year, he served as acting chairman of the Institute's Committee on the Undergraduate Program.

EXTERNAL RELATIONSHIPS

Exchange Program with Norwegian Technical University (NTH): This was the second year of a three-year exchange program between the MIT Ocean Engineering Department and the NTH Marine Technology Department. Four Norwegian students joined research groups here to undertake their diploma theses, and one NTH faculty member, Professor (and former Rector) Dag Kavlie, spent the year at MIT.

Maritime Research Enhancement Institute (MREI): The US Maritime Administration, Department of Transportation, has named MIT as a Maritime Research Enhancement Institute. In an open competition, MIT was one of only four institutions in the nation to be selected. Professor Marcus collaborated with the Center for Transportation Studies to achieve this status for MIT.

NAVSEA Professor of Ship Acquisition: The Naval Sea Systems Command (NAVSEA) has established a chair for the study and teaching of ship acquisition technology, policies, and procedures. A Memorandum of Understanding between MIT and NAVSEA provides for Navy funding for the chair for at least five years. Professor Marcus was appointed to the position.

T. FRANCIS OGILVIE

Artificial Intelligence Laboratory

The primary goal of the Artificial Intelligence Laboratory is to understand how computers can be made to exhibit intelligence. Two corollary goals are to make computers more useful and to understand certain aspects of human intelligence. Current research in the Laboratory includes work on robotics, vision, natural language, learning, reasoning and problem solving, deep expert systems, engineering design, computer-aided programming, supercomputing, and basic theory. Professor Patrick H. Winston works on the problem of learning from precedents. Professor Marvin Minsky develops general theories of intelligence and knowledge representation. Professor Robert C. Berwick studies fundamental issues in natural language, including syntactic and semantic acquisition. Professor David A. McAllester works on knowledge representation and automated reasoning. Professor Lynn A. Stein works on common-sense reasoning and on inheritance-based reasoning. Professor W. Eric L. Grimson, Professor Ellen C. Hildreth, Professor Berthold K. P. Horn, Professor Tomaso A. Poggio, and Professor Shimon Ullman do research in computer vision. Professor Christopher G. Atkeson, Professor Rodney A. Brooks, Professor Tomás Lozano-Pérez, Professor Marc H. Raibert, Professor Warren P. Seering, and Dr. J. Kenneth Salisbury work on various aspects of Robotics. Professor Randall Davis and Dr. Howard E. Shrobe work on deep expert systems that use both functional and physical models. Professor Karl T. Ulrich creates decision tools for product design and manufacturing. Dr. Charles Rich and Dr. Richard C. Waters explore the creation of intelligent programming environments. Professor Carl E. Hewitt studies distributed problem-solving and parallel computation. Professor Thomas Knight and Professor William J. Dally work on new computer architectures. Professor Gerald J. Sussman and Professor Harold Abelson lead work aimed, in part, at creating sophisticated problem-solving partners for scientists and engineers studying complex dynamic systems.

The Laboratory's 206 members include 22 faculty members, 19 academic staff, 33 research and support staff, and 132 graduate students active in research activities funded by the Defense Advanced Research Projects Agency, System Development Foundation, Office of Naval Research, Air Force Office of Sponsored Research, National Science Foundation, Analog Devices, Apple Computer, Bear Stearns Company, Draper Laboratory, Digital Equipment Corporation, E. I. duPont de Nemours, Exxon Research and Development Company, Fujitsu, General Dynamics, General Motors Research Laboratories, Hughes Research Laboratories, International Business Machines, ISX Corporation, Martin Marietta, Mazda Motor Corporation, MCC Corporation, McDonnell Douglas Aerospace, Mitsubishi, NASA, NATO, Sandia National Laboratory, Sharp Corporation, Siemens, Sloan Foundation, and Sperry Rand.

SPECIAL EVENTS AND BOOKS

During the past year, Professor Rodney Brooks was the co-recipient of the 1991 Computers and Thought Prize awarded bi-annually by the International Joint Conference on Artificial Intelligence. Professor Marvin Minsky was the recipient of the 1991 Research Excellence Award, also from the International Joint Conference on Artificial Intelligence.

Professor Gerald Sussman received the 1990 Karl Karlstrom ACM Distinguished Educator Award.

Professors Rodney Brooks, Randall Davis, Berthold Horn, Tomás Lozano-Pérez, Marvin Minsky, Tomaso Poggio, Marc Raibert, Gerald Sussman and Patrick H. Winston were named Founding Fellows of the American Association for Artificial Intelligence.

Books published this past year were *Principle-based Parsing: computation and psycholinguistics*, by Professor Robert C. Berwick, and *Object Recognition by Computer: The role of geometric constraints*, by Professor Eric Grimson.

NATURAL LANGUAGE UNDERSTANDING AND ACQUISITION

Professor Berwick and his colleagues have been building the next generation of natural language parsers and translators, based on modular linguistic theories. During the past year, a

completely modular parser for English was extended to cover Japanese and German. This is the first complete parsing implementation of the current linguistic theory that has been developed at MIT by Chomsky, Hale, Higgenbotham, and others. Unlike extant systems elsewhere that must use a large number of completely different rules for different languages, this system uses just a handful of the same principles, parameterized in a few ways, to cover very different languages. In addition, Berwick's group explored how to learn these parameterizations automatically from the actual language input that parents provide to children, assuming the kinds of visual input and naive physical reasoning capabilities that can be reasonably assumed to be present in young children. These systems can learn what words like *roll* and *walk* mean, or that *Mary* is a thing that is also a Noun, simply by "observing" the world around them.

Professor Berwick's group has further developed a highly efficient natural language parser that can analyze large amounts of text. For example, the entire 1988 *Wall Street Journal* can be analyzed in just several hours. During the past year, this parser was coupled with new tools for efficiently retrieving sentence analyses so that large amounts of text can be used for building natural language systems.

Large corpora of text are also being used for automatic dictionary learning. Raw text can be processed to yield the dictionary entries that any natural language processing system must tap. This project has led to new parsing techniques specialized for dictionary acquisition. The lack of accurate, complete dictionaries had been a major hurdle for natural language processing, but the new corpus-based methods promise substantial improvements. Further, they are likely to yield more detailed information about word usage than had previously been available.

OBJECT ISOLATION AND IDENTIFICATION

Work directed by Professor Ullman is exploring the problem of three-dimensional object recognition without three-dimensional models. This research has been divided into two main topics. The first topic is that of image partitioning and selection. The goal of this processing stage is to select from the image a portion that is likely to contain an object of interest. The selection processes gives the recognition system a capacity that is similar to the use of selective attention in human vision: it allows the system to concentrate its computational resources on the selected structure and apply to it additional processing stages that will lead eventually to recognition. Professor Ullman has developed a method for grouping together image edges and contours that are likely to correspond to a single object. This method appears to capture some basic properties of the grouping processes used by the human visual system.

The second topic is the representation of three-dimensional objects in memory, and the matching of these memory models with two-dimensional objects in the image. Towards this end, Professor Ullman has developed two approaches. The first, called the alignment method, finds and compensates for the transformations separating the viewed object and a given stored model prior to a matching operation. The second approach is novel in that objects are recognized without storing three-dimensional object model. Instead, objects are recognized by using combinations of two-dimensional views. The method is based on a theory that shows that any view of a three-dimensional object can be approximated by the linear combination of a small number of its views.

Other work on object recognition, directed by Professor Grimson, has centered on the development of systems for recognizing objects in cluttered, noisy, unstructured environments. Such systems have been demonstrated in a variety of environments, using visual, laser, sonar, and tactile sensors. They have also been incorporated as part of a hand-eye system, as part of a navigation system for autonomous vehicles, and as part of an inspection and process control system for industrial parts. Recent efforts have focused on establishing a formal theory on which to judge the efficacy and robustness of recognition methods, on exploring alternative matching schemes for recognizing objects, on grouping methods for preprocessing the

input data into salient sets of features, on the role of visual attention in recognition, and on the use of current recognition systems in practical applications.

Professor Grimson and his students also continue to work on the development and use of new stereo vision systems. Recent highlights include a novel, highly accurate stereo matching algorithm, the integration of stereo into a navigation system for a mobile robot, and work on object recognition from stereo data.

MOTION VISION AND PHOTOGRAMMETRY

Professor Horn and his students work on problems in motion vision. Currently, the extension of existing methods in the time direction is being explored. While one can get good motion information from just two image frames, distances to objects are determined only rather coarsely. One difficulty with using many frames is that one cannot generally assume that the motion is constant from frame to frame. It is possible, however, to incorporate a dynamic model of the vehicle carrying the camera to constrain the likely changes in motion over time. This enables application of the well-known techniques of Kalman filtering, although the problems here are highly non-linear and the equivalent "state" has an enormous number of degrees of freedom, typically one per picture cell, which prevents application of traditional direct approaches. In a related development, methods from computer graphics are used to predict the shape and position of an object at the next image frame time, based on the estimated shape and position and the estimated motion at the present time. Dramatic improvements in the accuracy of the reconstructed object shape are attained in this fashion, although after about ten frames the errors introduced by the prediction phase begin to balance out the improvements obtained from continuing the solution in time.

Because recovery of information about the world from a single cue such as motion parallax, binocular stereo disparity, or shading in images tends to not be very robust, there is now a great deal of interest in integrating information from multiple cues. The intimate integration of early vision modules will be required for most practical applications of vision systems. Professor Horn's approach to the problem focuses on intimate integration at the lowest level of vision modules. In the simplest case, this means interlacing iterations of different schemes for recovering shape, or more formally, constructing a compound functional that contains penalty terms for mismatching information available from both cues being considered. Preliminary results in integrating motion vision and shape from shading, and in integrating binocular stereo and shape from shading show great promise.

Finally, a chip has been designed and fabricated that computes the centroid and the orientation of an elongated object in the field of view. This chip is based on two theoretical results developed by Professor Horn, one of which allows the reduction of certain area based computations to contour computations; the other result uses the equivalence of two different uses of an electrical network to further reduce the number of computing elements required. The chip can process 5000 frames per second and so is performing at a rate that would require several hundred million arithmetic operations per second if it were to be carried out on a digital computer. Yet it requires very little in the way of support circuitry (other than a power supply), unlike competing special purpose digital devices. This is the first chip in a series of chips being developed, most of which will tackle problems in the field of direct motion vision methods.

Work on another special-purpose early-vision analog VLSI chip will be completed soon. This chip determines the "focus of expansion"—that point in the image towards which the camera appears to be moving. It does this without the need to detect and analyze image features. The result can be used to compute time to impact and possibly to recover shape information. This chip is considerably more complex than the centroid-and-orientation chip, yet will run at the equivalent of 1000 frames per second.

Work is also starting on the next step, a chip that can deal with arbitrary combinations of translational and rotational motions, provided that the scene being viewed is approxi-

mately planar. This chip will be again an order of magnitude more complex than the previous one and require considerable innovation before the circuitry can be fitted into the available space.

VISUAL MOTION AND HUMAN VISION

Professor Hildreth's research addresses the analysis of visual motion with special emphasis on biologically plausible theories. Her recent work focuses on the recovery of the three-dimensional motion and structure of objects, and follows three directions. The first is the computation of qualitative or partial information regarding 3-D structure and motion for tasks such as navigation. She developed a model that uses simple estimates of time-to-collision, based on the changing image size of moving objects, to reconstruct their 3-D trajectories through space, and is conducting perceptual experiments to test whether such a strategy is used by the human visual system. Second, she has been exploring the integration of 3-D structure-from-motion recovery with the overall process of surface reconstruction. This latter project has led Professor Hildreth to study the interaction between motion analysis and binocular stereopsis. She is pursuing a model that computes the 3-D positions and velocities of features over an extended time, through incremental improvement, by combining constraints both from the projected 2-D motions of the points in the image and the temporal changes in their stereo disparity.

THE VISION MACHINE

The main project of Professor Poggio's group has been the Vision Machine—a computer system that attempts to integrate several visual cues to achieve high performance in unstructured environments for the tasks of visual recognition and navigation. The Vision Machine is also a test-bed for measuring progress in the theory of early vision algorithms, their parallel implementation and their integration, up to recognition of 3-D objects. They have developed and implemented several parallel early vision algorithms computing edge detection, stereo, motion, texture, and color in close to real time. The integration stage attempts to derive a map of the surface discontinuities in the scene, with a partial labeling of the intensity edges in terms of their physical origin. They have interfaced the output of their integration stage with a parallel recognition algorithm.

During the past year one of the main achievements has been the design and fabrication of an analog VLSI chip embedding one of the earliest Vision Machine algorithms—edge detection—integrated with a CCD imager on the same chip.

Current work focuses on recognition and on machine learning. Learning an input-output mapping from a set of examples, of the type that many neural networks have been constructed to perform, can be regarded as synthesizing an approximation of a multi-dimensional function. They have recently developed a theoretical framework that shows the equivalence between a powerful approximation technique called regularization and a class of three-layer networks that they call Hyper Basis Functions (HyperBF). The theory was originally developed without any direct biological motivation. It turns out, however, that HyperBF networks may have a very simple and appealing interpretation in terms of neurons with Gaussian-like receptive fields and modifiable synapses (according to a Hebb-like rule for instance). In addition, a HyperBF model of 3D object recognition has been recently supported by psychophysical data about human vision and is consistent with neurophysiological data on cortical neurons involved in face recognition.

The plan for the future involves four main directions of research: further development of the mathematical part of the theory; refinement of the technique for applications such as object recognition, face recognition, hyperacuity tasks, synthesizing robot control systems, and predicting time series; study of how to use the technique as a building block for more complex architectures, involving, for instance, feedback and hierarchies; and exploration of the biological relevance of the theory for explaining how some parts of the brain might work.

MOBILE ROBOTS

Professor Brooks and his staff and students have been building mobile robots and testing their theories of how to organize intelligence. They have made progress on a number of fronts: integrating complex systems into kilogram scale robots, developing simple visual reflexes for mobile robots, understanding how multiple robots can work together and producing extremely tiny robots.

During the past year the first prototypes of a new generation of six-legged robots were demonstrated, incorporating 23 actuators, 150 sensors, and 11 processors in a 2.5 kilogram package. The initial programs for this new generation of robots rely on a new computational model of hormone-like arbitration of behaviors. A number of low computation visual reflexes, such as a loom detector, a person head nodding-or-shaking detector, and a visual proximity sensor for robots were designed, formally analyzed and implemented, and demonstrated individually. A set of 20 identical mobile robots were completed and initial programming tests were completed as a prelude to studying group interactions among multiple robots. A sub-millimeter thin film piezo-electric motor built on a silicon substrate using photolithographic techniques was demonstrated spinning, and progress was made in developing finite element models in order to understand its behavior.

PLANNING GRASPING MOTIONS

Professor Lozano-Pérez and his associates have continued development and testing of the Handey task-level robot system. The Handey system plans all the motions required for pick-and-place tasks involving planar-faced parts. Handey first locates one of the parts on the robot's work table, then plans where to grasp the part so as to avoid all nearby obstacles. Next, Handey plans a collision-free path for the complete robot to reach the part, selects a sequence of regrasping motions (if necessary) to achieve a grasp compatible with the final destination, and finally, plans a path to place the part at the specified destination. Handey can deal with jointed parts, coordinate the motions of multiple robots, and grasp complex polyhedral objects using Dr. Salisbury's three-fingered hand. Handey can plan collision-free motions using a bitmap representation of configuration space computed using the Connection Machine. This parallel implementation is made possible by a simple, yet powerful algorithm for computing configuration-space obstacles. Handey's grasp planner has been recently redesigned to use a new configuration space approach which is faster and more reliable than the old algorithm.

LEGGED LOCOMOTION

Professor Raibert and members of the Leg Laboratory have studied legged locomotion in a variety of legged systems, including laboratory robots and computer simulations of animal like systems. During the past year, they have controlled the behavior of a three-dimensional biped robot with telescoping legs, computer and physical models of a kangaroo, and a computer simulation of an ostrich.

ROBOT AND HUMAN ARMS AND HANDS

The Salisbury articulated hand has been mounted on a PUMA arm and has served as a test bed for a wide range of grasping and path planning experiments. Dr. Salisbury's group is currently using this hand/arm system to develop sensor reactive grasping strategies aimed at locally robust object acquisition in both terrestrial and zero-gravity environments. The integration of three six-axis force sensing fingertips into the system has provided the sensory information necessary for implementing a new grasp-force redistribution reflex for securely handling delicate objects. Professor Lozano-Pérez's group has been using this system to demonstrate and develop their geometry-driven grasp planning system. A system which recognizes objects from kinesthetic information has been developed.

A high performance cable driven arm (WAM), developed by Dr. Salisbury's group, has been the focus of a number of novel manipulation and control investigations. The arm takes advantage of its inherent force controllability in performing a new class of operations known as *whole-arm manipulation*. Because the arm is designed to perform useful operations with

all its surfaces, not just its end-point, it is able to push, grasp, and operate upon objects in ways impossible for traditional robots. Professor Slotine's group from MIT's Non-Linear Systems Laboratory has developed and implemented a series of adaptive non-linear control systems for the WAM arm which permit significantly improved performance in free and constrained motions. In addition, they have developed an approach for robust and predictably stable force reflecting teleoperation in the presence of time-delay. A successful demonstration of stereo-vision-directed catching of objects thrown to the arm has been made. A new integrated hand/wrist system is being developed for the arm which will be used in robotic and telerobotic applications ranging from real-time catching of rotating objects to unstructured grasping.

During the past year, Professor Seering's group has made advances in understanding the dynamic response characteristics of robot arms. The focus of the group's work has been on system identification and on exploring control strategies for improving robot performance under force control. Efforts are also ongoing on minimizing undesirable vibrations in dynamic systems. In collaboration with NASA the group has been working to improve the response of the space shuttle robot arm.

Professor Seering's students have also been looking for ways to use computers to help mechanical designers. As part of this activity, they have been working to capture design documentation so that it can be retrieved efficiently and at the desired level of detail by a designer. Some of this work builds on work on decision rationale representation initiated in Professor Winston's group.

MOTOR LEARNING

Professor Atkeson and his group have been exploring paradigms for motor learning so as to understand how performance can improve with experience in humans and robots. Previous work focused on parameter identification, model and coordinate system calibration, and model-based control. An important emphasis has been model-based learning, in which a model of the controlled system is used to help map performance errors into command corrections. Models of a task can be used in addition to models of the system components to accelerate learning. Another area of research has been memory-based learning algorithms, where an associative, content-addressable memory is used to learn an internal model and improve robot performance on a particular task.

MIXED SYMBOLIC AND NUMERICAL COMPUTATION

The research of the MIT Project for Mathematics and Computation (Project MaC), under the direction of Professors Abelson and Sussman, is working to demonstrate breakthrough applications that exploit new computer representations and reasoning mechanisms that they have developed. These mechanisms enable intelligent systems to autonomously design, monitor, and understand complex physical systems, through appropriate mixtures of numerical computing, symbolic computing, and knowledge-based methods. They call this mixed approach *intelligent simulation*.

Systems incorporating intelligent simulation can automatically prepare numerical experiments from high-level domain descriptions. They automatically select and configure appropriate numerical methods. They actively monitor numerical and physical experiments. They automatically analyze the results of such experiments, using domain knowledge to interpret the numerical results, and they report these results to their human users in high-level qualitative terms. In favorable cases intelligent simulation programs can automatically configure special-purpose hardware for efficient execution of computationally demanding numerical experiments.

The group has demonstrated the basic capabilities of intelligent simulation systems. They have implemented computer programs that interpret numerical simulations of nonlinear systems, automatically producing summary descriptions similar to those in the published literature. They have shown that programs can harness techniques from computer vision to

“look at” simulation data and isolate regions of interesting behavior, and they have demonstrated this automatic analysis by discovering new results of current interest in theoretical hydrodynamics. They have constructed a “Supercomputer Toolkit” that permits the flexible configuration of a variety of special-purpose computers, and places in our hands the kind of low-cost, high-performance numerical computation that will not be generally available for another five years.

Their objective now is to capitalize on the foundations they have built, and to demonstrate revolutionary applications of intelligent simulation technology. They expect to construct measuring instruments that automatically formulate high-performance dynamical models of the systems being measured. Such instruments will measure the parameters of physical systems with unprecedented accuracy. They intend to implement supervisory real-time controllers that autonomously explore and interpret the phase-space geometry of the systems they are controlling. They believe that such programs will achieve spectacular performance in the real-time control of nonlinear systems. And finally, they propose to fabricate intelligent structures that exploit high-performance embedded computation to attain great structural strength despite low cost in mass and materials.

MODEL BASED REASONING SYSTEMS

Professor Davis, Dr. Shrobe, and their associates are building knowledge-based systems that use models of structure, function, and causality to perform a wide range of problem solving and reasoning tasks. The systems they have built can reason about how a device works and how it fails in a manner similar to an experienced engineer. This is an important advance in the art of knowledge-based systems construction, because it provides the system with a more fundamental understanding of the device than is possible using traditional approaches.

Previous work produced a number of systems that reason in this fashion, including: a troubleshooting system that can apply these techniques to designs that include memory and complex time-dependent behavior; a system that generates diagnostics from a circuit description, capable of generating tests for devices considerably more complicated than those handled by existing test generators; a system that functions as an assistant in design for testability; a system that designs devices by reasoning from fundamental principles of qualitative physics and qualitative mathematics; a system to demonstrate how a program can learn from experience, using two different forms of generalization along with a set of guidelines that indicates when to remember and generalize, and when to simply re-derive the result; and a system capable of designing representations for an interesting class of analytical reasoning problems.

Work during the past year has produced two new systems. One assists with consensus knowledge acquisition, the task of assisting two or more experts in coming to consensus on the knowledge base necessary for a specific task. The second explored the fundamental problem of model selection: how does an engineer decide which model (that is, which approximation) to use when solving a problem.

New work is focused on understanding how things work in a variety of domains, including simple mechanical devices like four-bar linkages, and mechanistic explanations of biological phenomena. Examples of understanding include the ability to produce descriptions of device behavior from a description of their structure, the ability to predict behavior under unusual circumstances, and the ability to redesign to fit those new circumstances.

ENGINEERING PROBLEM SOLVING AND DESIGN

Professor Ulrich and his students have been working on computational tools for product design and manufacturing. One project aims at encoding and exploiting product development information as it is discovered and modified in the course of a product development effort. This research is being conducted in the context of the actual development of a new power tool.

Another project focuses on the problem of enforcing producibility constraints during the specification of the geometry of structural parts. This work is motivated by the needs of large engineering projects, commercial airframe development for example, involving thousands of structural parts.

Finally, Professor Ulrich and his students are exploring the use of a production process as the basic operating metaphor for computer-aided design systems. This work has grown out of previous work on novel human-computer interfaces for computer-aided design.

PROGRAMMER'S APPRENTICE

Dr. Rich, Dr. Waters, and other members of the Programmer's Apprentice group use programming as a domain for studying and attempting to duplicate human problem solving skills. In the near term, they seek to produce a system, called the Programmer's Apprentice, which provides intelligent assistance in various phases of the programming process. Over the past year, they have completed a demonstration of automated program optimization. They are also working on automated reverse engineering (reconstructing the design of a program from just the source code) and intelligent assistance for software design.

SYMBOLIC PARALLEL ARCHITECTURES

The Symbolic Parallel Architecture group, under the direction of Professor Knight, has been developing a uniform, large scale, parallel symbolic supercomputer called *Transit*. Unlike most parallel machines, this architecture has been explicitly designed to support a wide range of parallel programming models with excellent performance. The key realization is the critical importance of low latency in the processor-to-processor communications path. This low latency communications is used as a substrate for coherent caches and processor-to-processor message passing. The implementation of *Transit* is being done in three phases: construction of the routing network, coherent cache implementation, and finally processor design. The routing network is currently under detailed design and simulation. Its construction involves novel three-dimensional packaging and cooling technology, novel VLSI techniques for chip-to-chip communications, and a very simple, high speed routing component. The initial prototype is expected to yield a remote memory access latency of about 300ns and a per-port peak bandwidth of 800 megabaud. The aggregate switch bandwidth approaches a terabaud.

Initial design of a massively parallel hybrid analog/digital machine for quickly solving coupled constraint problems has also begun. The architecture capitalizes on the ability of resistive meshes to express and solve constraint and optimization problems. Dynamic problems can be solved using a new approach of converting dynamic systems into four-dimensional static problems. The temporal evolution of solutions is then available in a spatially accessible array.

CONCURRENT VLSI ARCHITECTURE

The Concurrent VLSI Architecture Group under the direction of Professor Dally has been developing techniques for applying VLSI technology to solve information processing problems. The group has been developing the J-Machine, a fine-grain concurrent computer that offers supercomputer performance and tests a number of new concepts in interconnection networks, addressing mechanisms, processor architecture, and concurrent software systems. During the past year, the group completed the design of a single node of the J-Machine, known as the Message Driven Processor. The MDP chip was fabricated by our industrial partner, and first samples of the chip worked correctly, at greater than predicted performance. They have built an initial multi-node system, and expect to complete a 1024 node prototype J-Machine by year's end. They are continuing to develop system software, languages, applications, and high-speed peripherals for the machine. They have written a distributed operating system and compilers for the Concurrent Smalltalk and Concurrent Aggregates programming languages. As one of the machine's initial applications, they are developing a high performance, reliable transaction processing system.

MESSAGE-PASSING SEMANTICS

The Message-Passing Semantics group, under the guidance of Professor Hewitt, has been developing the foundations for Open Systems that perform robustly in changing environments. An Open System is one that is always subject to unanticipated communications from outside and whose operations are subject to indeterminate results. Robustness means the ability to keep commitments in the face of conflict and indeterminacy, which are ubiquitous in Open Systems. Robust computer systems are needed to meet the challenge of Open Systems to gain from the advantages of openness while meeting the requirements that are imposed by openness. Open Systems undergo continual change: some change coming from within, through communication among internal parties, some from without through interaction with the environment. The primitives of ultraconcurrent systems are called ACTORs. These can be organized into systems of ORGs (Organizations of Restricted Generality). The Actor model provides a scientific and technological basis for Open Systems because it supports dynamic reconfigurability, compositionality, and extensibility. The ORG model provides a scientific and technological basis for organizational systems because it supports teamwork, management, liaison, and organizational representation. The group's research focuses on the theoretical, architectural, and linguistic aspects of organizational systems composed of humans and telecomputer systems.

SOCIETY OF MIND

Professor Minsky has continued to develop the theory of human thinking and learning called the "Society of Mind." This theory explores how phenomena of mind emerge from the interaction of many disparate agencies, each mindless by itself. For example, one aspect of the theory explains the combination of knowledge representations in different realms of thought as the basis for analogy; another aspect is a "re-duplication" account of natural language, in which grammatical forms are seen as emerging directly from expressive requirements rather than from conventions that communications are forced to fit.

Professor Minsky has continued his interest in the limits and potentials of "connectionist learning systems" and their role in distributed cognitive accounts like the Society of Mind. He is actively considering how such systems may be combined and interconnected in a way that avoids the serious scaling problems of unstructured connectionist systems.

LEARNING FROM ANALOGOUS PRECEDENTS

Professor Winston's group has concentrated recently on developing representations that enable learning and reasoning by analogy. During the past year, considerable progress was made on the particular problem of representing decision rationals. The key problem is to find a suitable, framelike vocabulary for describing decisions. By capturing a decision rational in a form that facilitates symbolic reasoning, subsequent decisions need not go over the same ground. Additionally, decision can be seen from a variety of perspectives, providing a sort of symbolic what-if capability, leading to a better understanding of how biases influence conclusions.

Other work in Professor Winston's group has focused on the problem of representing change qualitatively, such that a remembered sequence of changes can be used as a precedent for understanding how some subsequent situation is evolving. The experimental domain, at the moment, is that of encyclopedia-style texts describing, for example, how rockets work.

AUTOMATED FORMAL REASONING

Professor McAllester has been building and testing automated reasoning systems. These reasoning systems incorporate a variety of new algorithmic techniques that allow effective automated reasoning about topics that are beyond the scope of any previous reasoning system. For example, the new reasoning systems have been able to verify proofs, starting with only the axioms of Zermelo-Fraenkel set theory, of the Stone representation theorem in lattice theory. This theorem involves an ultrafilter construction and is similar in complexity to the Tychonoff theorem that a product of compact topological spaces is compact. The novel algorithmic techniques include the integration of congruence closure into general theorem

proving, monotone closure for reasoning about semantic types, focused forward chaining, and the incorporation of universal generalization into constraint propagation. In addition to evaluating automated reasoning systems in terms of their ability to verify abstract mathematical theorems, Professor McAllester is studying the application of automated reasoning systems in software verification. In particular, Professor McAllester has begun to concentrate on the special case of verifying computer programs to be “uncrashable.”

COMMONSENSE REASONING

Professor Stein’s group works on commonsense reasoning. In order to build machines with common sense, we must first understand what types of behavior constitute common sense. By considering the form of reasoning that we are engaging in, we can abstract principles that capture our commonsense intuitions. For example, in reasoning about action and change, our understanding of causation is central. By formalizing a theory of causation, Professor Stein has both solved the well-known Yale shooting problem and laid the foundations for temporal reasoning critical to story understanding, planning, and numerous other tasks. Similar work in hierarchical (inheritance) reasoning has been extended this past year to include a prototype implementation. In addition to formalizing the “right” answers, we also need to consider how this behavior might be built or might emerge from human or robotic experience. This past year, Professor Stein began a project to demonstrate that a robot designed for navigation could perform cognitive tasks by *imagining* that it is acting on the world. By recycling the existing behavior, this imagined-interactive system uses a minor modification to produce qualitatively different behavior. In the future, she plans to explore extensions of this technique to other systems, adding more sophisticated cognitive skills to primitive robots.

PATRICK H. WINSTON

DIRECTOR

Biotechnology Process Engineering Center

INTRODUCTION

The Biotechnology Process Engineering Center (BPEC) is an interdepartmental center at the Massachusetts Institute of Technology. This Center is funded by the National Science Foundation (NSF) under the Engineering Research Center Initiative and was established in May, 1985. BPEC was recently approved for an additional five years of support beginning February, 1991 through January, 1996. As an interdepartmental center, the BPEC reports to the Dean of Engineering, Professor Joel Moses. The Director of the Center is Daniel I.C. Wang, Professor of Chemical Engineering. There are 3 associate directors who assist in the overall operations of the Center. They are Charles L. Cooney, Professor of Chemical Engineering and Associate Director for Industrial Involvement; Gregory N. Stephanopoulos, Professor of Chemical Engineering and Associate Director for Research; and Anthony J. Sinskey, Professor of Biology and Associate Director for Education and Cross-Disciplinary Affairs.

The goal of this Center is to create a new breed of professionals to enhance this Nation's international competitiveness in biotechnology manufacturing. To achieve this goal, this Center focuses its efforts through education, research, and industrial involvement. Cross-Disciplinary educational and research collaborations are especially important components within the Center's activities.

A total of fourteen faculty members participated in the Center's activities this past year. BPEC faculty are drawn from 4 departments at MIT. Within the School of Engineering, we have faculty from the Department of Chemical Engineering and the Department of Electrical Engineering and Computer Science. Within the School of Science, we have faculty from the Departments of Biology, Chemistry, and the Whitehead Institute. The BPEC also has one faculty member from the Department of Chemistry at Harvard University. In addition to the fourteen faculty members, several students, visiting scientists, etc. hold appointments at the Center.

A summary of the BPEC personnel during Fiscal 1991 is tabulated below.

• MIT Undergraduates (UROP)	= 72	(10 Departments)
• Non-MIT Undergraduates (REU)	= 22	(17 Universities)
• Graduate Students	= 51	(4 Departments)
• Technical Assistants	= 5	
• Post-Doctoral Associates	= 13	
• Visiting Scientists & Engineers	= 27	
• Visiting Faculty	= 1	
• Other Administrative Personnel	= 14	

TOTAL 205

The major financial support is provided by the National Science Foundation. Additional support for graduate educational activities for the MIT students is provided by the National Institutes of Health

(NIH-NIGMS). The Center also secured unrestricted funds from outside sources. Industrial donations were received in the form of contracts, fellowships, equipment, and software.

EDUCATIONAL ACTIVITIES

The Center's faculty members taught an interdisciplinary undergraduate course, 7.52J/10.56J, Biotechnology of Mammalian Cells. Funds to the teaching assistants for this course were provided by the Center. In addition, all of the BPEC faculty taught in their respective departments in existing courses which dealt with biotechnology. Two very active undergraduate programs continued this past year, the Undergraduate Research Opportunities Program (UROP) and the Research Experience for Undergraduates (REU). Seventy-two UROP students participated in the Center's research program this past year, ten of whom were minority. In addition, an undergraduate outreach program funded separately by the National Science Foundation under the Research Experience for Undergraduates (REU) supported twenty-two non-MIT students. These non-MIT REUs were from seventeen different universities and colleges throughout the United States. We continued our seminar program entitled, "UROP and REU Seminar" in which the undergraduates presented on a weekly basis their research experiences to the Center's personnel.

At the graduate level, we have continued to bring interdisciplinary concepts into the course teachings. We successfully completed our second year on the Interdepartmental Biotechnology Program (IBP) which was officially inaugurated in 1989. Funding for this program is provided by the NIH, a training grant designed to support fourteen pre-doctoral candidates for the first year and second year and twenty-one candidates for the third through the fifth year. This program involves thirty-three faculty members from MIT representing the Departments of Biology, Chemistry and Chemical Engineering. The Center's Director, Professor Daniel I.C. Wang, is also the director of this new program. With the start of the third year new cross-disciplinary courses and further industrial involvement are being developed for this program.

Industrial educational activities were achieved through the Special Summer Course Program at MIT. In 1990, 2 special summer courses under the auspices of the BPEC were presented. They were, "Fermentation Technology" and "Downstream Processing". During 1990-1991, 3 mini-courses were taught by BPEC Faculty at industrial sites. They were: "Fermentation Technology and Downstream Processing" at Merck, Sharp and Dohme; "Bioreactor Aeration and Agitation and Scale-UP in Bioreactors" at Pfizer Corporation; and "Fermentation and Bioprocess Technology" in Singapore.

CURRENT RESEARCH

The vision and goal of this ERC are to develop advanced concepts for the manufacturing of complex proteins and to train a new breed of professionals with the cross-disciplinary skills needed to support the biotechnological industry. Many therapeutic proteins cannot be

made in prokaryotic organisms and thus new concepts are needed to synthesize and recover these materials from animal cell cultures.

The research thrusts of the BPEC are designed to solve near and long term problems, and as such, have impacted on US biotechnological manufacturing capabilities and international competitiveness. Training people, performing research, and working with industry, are central BPEC goals and are the mechanism, through which we will deliver the benefits of our work.

Two research thrust areas are being pursued in this Center. The first area is focused on the "Engineering and Scientific Principles in Therapeutic Protein Production". The BPEC mission in Thrust I takes a systems approach to develop an understanding of the interrelationships between performance of the a bioreactor and its design as influenced by its physical and biological environment. Important relationships to be established include the number of living mammalian cells in a given bioreactor and their functions and the amount and quality of product. This knowledge will allow one to design better bioreactors and systems; provide proper surfaces for cell growth and product formation; formulate optimal media; and finally optimally operate and control the bioreactor for the manufacture of complex therapeutic proteins.

The second thrust area is focused on "Integration of Process Engineering and Science of Therapeutic Protein Purification". The goal in manufacturing therapeutic proteins is production of very pure, homogeneous and fully functional protein preparations. Some of the engineering problems in achieving this goal originate in upstream manufacturing, e.g. heterogeneity in post-translational processing, insoluble aggregate formation, impurity and contaminant introduction. Many other problems develop in the course of the downstream process itself, e.g. specific and non-specific surface interaction, solution and solid phase stability, variable refolding and aggregation during refolding. The mission of the Center is to establish the relationship between the bioprocess environment on one hand and process yield and product quality obtained from protein purification on the other. In order to accomplish this mission, Center research must develop the science base underlying the observed phenomena and also facilitate the application of the knowledge to the improvement of product purification operations.

INDUSTRIAL COLLABORATIONS AND TECHNOLOGY TRANSFER

Industrial collaborations and technology transfer are important goals of this Center. In 1986, our Industrial Consortium Program was established. In 1990, there was a total of sixty-four companies in this Program, representing the entire spectrum of the biotechnology industrial sectors. During 1990-1991, a total of thirty-six collaborative industrial projects were in place with an additional eleven industrially sponsored research projects. Lastly, during 1990-1991, there were seventeen industrial scientists and engineers in residence at this Center.

As part of its effort to foster technology transfer, the BPEC has established an Industrial Consortium Office. Its responsibilities include coordinating company visits; disseminating research

abstracts, published papers, and student theses; organizing workshops and symposia; and maintaining a database of BPEC research projects. This office works closely with the BPEC faculty, BPEC students, the MIT Industrial Liaison Program, and the MIT Technology Licensing Office in order to serve company needs.

Topic-oriented workshops play an important role in BPEC's technology transfer program. By bringing company representatives together to discuss a common topic, these workshops provide a forum for education and company-company interactions. The BPEC has held workshops on the following topics: animal cell science and technology, downstream processing, process control and scale-up, advances in membrane technology for bioprocesses, bioinstrumentation, industry regulation, protein expression systems, bioremediation technology, and biosensors. Typically, these workshops draw 30 to 40 attendees from 20 to 30 companies. The Center has also attempted to hold these meetings at locations other than MIT, so as not to create a geographical bias towards certain companies.

Below is a summary on some of the other achievements of the BPEC during 1990-1991:

• Publications	= 283
• Presentations at Conferences and Symposia	= 132
• Industrial Seminars	= 39
• University Seminars	= 63
• Theses	= 21
• Company Visitors to BPEC	= 99

NEW APPOINTMENTS AND NEW INITIATIVES

Four new faculty appointments to the Center were made during the past year. However, two previous faculty members withdrew bringing the total number of faculty to fourteen. The funds for the Minority Out Reach Program were not released this past year. However, we were able to continue minority participation through the REU program by appointing 3 minority students.

Daniel I. C. Wang

Center for Advanced Engineering Study

The Center for Advanced Engineering Study (CAES) was founded in 1963 for the purpose of developing educational programs that provide opportunities for practicing engineers, scientists, and managers in industry, government, and educational institutions to attain and maintain the competence needed to exert technological leadership. Alfred P. Sloan, Jr. provided both the impetus and the funds to get the center started. Building 9 has been the home of CAES since its completion in 1968.

To achieve its objectives, CAES has traditionally offered two types of educational programs, at the workplace and on-campus, for the practicing professional. For those at the workplace, the center provides studio-based and classroom-based video courses which are produced at the center in collaboration with MIT faculty and research staff. Richard J. Noyes is the director of the video-based programs. The on-campus, Advanced Study Program, directed by Dr. Paul E. Brown, provides the participants with individualized study and/or research that is tailored to their backgrounds and designed to meet their needs and the objectives of their employers.

During the 1990-91 academic year, 82 professionals participated in the Advanced Study Program, 30 from the United States and 52 from 15 other countries. These Fellows attended regular graduate and undergraduate subjects that suited their needs. In addition, many of them performed individualized studies guided by faculty members and several participated in ongoing research programs. Also, the center sponsored several subjects that are of particular interest to the Fellows, such as Project Management and Management of Technological Change. These subjects are listed in the MIT course catalog and are, of course, open to MIT students. CAES in addition, offered informal evening classes in Artificial Intelligence and Expert Systems.

The Fellows in the Advanced Study Program are provided with study offices, computer facilities, and a videotape library with viewing facilities. The computer facilities include IBM and Macintosh computers, and DEC VAX workstations connected to the Project Athena Network, which integrates computers into the educational environment in all fields of study. We also offer a weekly luncheon seminar at which the Fellows give brief presentations on their work. Center staff and faculty also make presentations at these seminars.

CAES video-based educational programs focus primarily on recent developments in MIT research. These video courses are used at the workplace by a broad spectrum of businesses, government agencies, and educational and training institutions to instruct their engineers, scientists, and managers. Recent video releases include: Management of Innovation by Professor Eric Von Hippel; Fundamentals of Image Processing by Professor William Schreiber; Demonstrations in Lasers and Optics by Professor Shaoul Ezekiel; Taguchi Quality Engineering System for Robust Design by Professor Don Clausing. In addition, the center produced a new condensed version of the Deming Videotapes entitled "The Essential Deming." Courses in development include: 2-D Signal and Image Processing by Professor Jae Lim; Understanding Lasers and Their Applications by Professor Ezekiel; and Enhanced Quality Function Deployment by Professor Clausing. All video courses are professionally taped by center staff either in the CAES television studio in Building 9 or in designated classrooms.

In order to enhance the Institute's well established role in continuing education, CAES is always searching for new initiatives in educational programming to strengthen MIT's coupling to Industry, both local and out-of-state. One such initiative is "A Day with an MIT Professor," a non-credit on-campus program held on Saturdays. Participants spend a day with a faculty member in an informal atmosphere which gives them an opportunity to examine a specific topic in depth through direct interaction with the faculty member as well as with the other participants. These programs are tutorial in nature and emphasize fundamentals as well as recent developments.

This concept was successfully tested on two Saturdays in the spring of 1990 with 19 programs. These programs included: Technology Transfer and Reward Systems for Professionals by Professor Thomas Allen; Advances in Multivariable Control System Design by Professor Michael Athans; Nonlinear Finite Element Analysis of Solids and Structures and Nonlinear Finite Element Analysis of Fluids and Fluid-Structure Interactions by Professor Klaus-Jurgen Bathe; Mobile Robots by Professor Rodney Brooks; Concurrent Engineering by Professor Clausing; Lasers-- Who Needs Them and Optical and Fiberoptical Sensors by Professor Ezekiel; Project Management by Professor Ernst Frankel; Smart Engines by Professors Edward Greitzer and Alan Epstein; Enzyme Technology by Professor Alexander Klibanov; Corrosion Resistance of Advanced Engineering Materials by Professor Ronald Latanision; Polymers and Polymer-Based Composites by Professor Frederick McGarry; Cryptographic Security by Professor Silvio Micali; Heat Transfer in Design and Processing by Professor Borivoje Mikic; Knowledge-Based Expert Systems for Engineering by Professor Duvvuru Sriram; The Dynamics of Innovation in Industry by Professor James Utterback; Optical Information Processing by Professor Cardinal Warde; and 3D-Computer Graphics by Professor David Zeltzer.

For a broader outreach, we have begun broadcasting, by satellite, timely management and engineering subjects. These broadcasts are organized around single themes that focus on practical applications and are usually presented by one speaker over several hours in a single day. The transmissions are carried on KU-band frequencies to businesses, government agencies, and universities via the NTU network. Two satellite broadcasts were scheduled during the fall of 1990: Taguchi Quality Engineering System for Robust Design by Professor Clausing, and Laser Fundamentals and Applications for Managers and Engineers by Professor Ezekiel. A second series was conducted during the spring of 1991 and included the following topics: Lean Production: Innovations in Manufacturing and Product Development by Professors Daniel Roos and Michael Cusumano; Understanding Lasers & Their Applications by Professor Ezekiel; Concurrent Engineering by Professor Clausing; The Dynamics of Innovation in Industry by Professor Utterback; 2-D Signal Processing and Image Processing by Professor Lim; and Technology Transfer/Reward Systems for Professionals by Professor Allen. A third series is planned for the winter of 1992.

The summer of 1991 will be the fifth year of CAES participation in a unique initiative to provide continuing education for engineering faculty in US colleges. Special two-week intensive courses are offered by universities and industrial organizations with the major support coming from the National Science Foundation. Over 690 faculty have attended such programs so far. CAES plays a key role in the organization, coordination, and administration of this program under the aegis of the American Society for Engineering Education (ASEE).

The CAES Video Production Services group continues to provide a full range of services for the Institute. Any video need can be taped efficiently and at a reasonable cost at any location or at the CAES studio. Facilities and services include, among others, a full-production television studio, a television classroom, videotaping on location, on-line and off-line editing, plus tape duplication.

SHAOUL EZEKIEL

Center for Technology, Policy, and Industrial Development

Education and research at the Center for Technology, Policy and Industrial Development (CTPID) targets policy issues raised by the impacts of science and technology on individuals and society. Many of these issues are international in scope, forming large-scale complex systems of global significance. Such systems are characterized by major technological or scientific components, require cooperation among many decision-making groups in public and private spheres, and have important implications for the quality of life. They include, for example, the physical and social environments, the structures of international industry, and the emergence of a global communications system. Decision-making in all of these systems requires a deep understanding of both specific technologies and the policy process.

CTPID acts as a catalyst bringing together faculty and students with strong specific skills to pursue interdisciplinary educational, research, and outreach activities in an effort to understand and facilitate policy making for large-scale complex systems. The Center supports several major programs, including the International Motor Vehicle Program, the Hazardous Substances Management Program, and an educational component, the Technology and Policy Program, as well as many individual, often related, research projects. These programs are undertaken cooperatively with other departments, laboratories, and centers of research and teaching at MIT. In addition to bringing together MIT personnel, the Center focus on "real world" problems has led to the creation of strong links with public and private groups outside the Institute. The perspectives of the builders, managers, and end-users of technology enable researchers to address the most relevant questions and to frame new methods of inquiry.

During six years of growth and change at CTPID, we note the evolution of a special emphasis on (1) internationalization of both the drivers and the effects of technologies; (2) the interconnected quality of the physical, economic, and social environments; and (3) the need for further adaptation of the decision-making processes available to policy makers in public and private sectors. This tripartite emphasis has shaped developments in the educational, research, and public service activities of the Center this year.

RESEARCH

The Center is responsible for a broad range of interdisciplinary research projects. Rather than describing each of the projects briefly, we examine three programs on the environment, industry studies, and large-scale systems.

Industry Studies

The Center concluded the International Motor Vehicle Program (IMVP) with an international conference in Japan and the publication of the book *The Machine That Changed the World* which summarizes the principal findings of the Program. The book has had a major impact since its publication in October. It currently is in its seventh printing; it was selected as the best business book of the year by the Financial Times and it will be translated into seven languages. The principal conclusion of the Program is that the best Japanese companies have developed a fundamentally different and superior approach to the production process. A new "lean production" paradigm is developed and contracted with Western mass production approaches.

Based on the success of the Program, discussions were held with the Alfred P. Sloan Foundation regarding a second phase of the IMVP. The Sloan Foundation has provided major funding support to extend the Program for an additional three-year period.

The new phase of the program, which began this year, has four principal components:

- (1) To build upon and expand our understanding of best practice techniques.
- (2) To examine how best practice techniques are broadening to include environmental considerations.
- (3) To examine how acquisition and utilization of new technologies influence best practice.
- (4) To examine how the motor vehicle industry is adapting innovative best practice techniques and reorganizing corporate structure and activities in an international context.

The four foci emphasize important, mutually compatible elements. The first examines best practice techniques in manufacturing and product development. It builds upon the research studies initiated in Phase One of the Program.

The second acknowledges perceived increased tensions between economic competitiveness objectives and social/environmental concerns. After a decade of relaxed regulation, environmental issues (often of an international dimension) are of primary concern to the auto industry and will impact upon product development and manufacturing practice.

The third recognizes that best practice is continually improving, particularly with regard to technology. In an era of rapid technological innovation, it is unrealistic for any one company or even any one country to expect to be technologically self-sufficient. Thus, new cooperative arrangements -- assembler/supplier agreements, joint product development ventures among otherwise competing firms and public and private consortia -- are developing for the purpose of acquiring and utilizing technology. Of particular interest is the development of intelligent vehicle highway systems (IVHS) which will involve participation of both the public and private sector in large-scale development efforts.

The fourth recognizes that the integration of strategies -- with respect to business, technology, organizational and human resource issues -- is a hallmark of lean production. The Program will examine how companies develop and implement innovative approaches to transition from mass to lean production. The examination will include innovation with traditional brownfield assembly plants, new greenfield transplants, and new operations such as the Saturn Corporation. An important aspect of the industry restructuring process is how to facilitate better relationships between government and industry and assemblers and suppliers.

Environmental Studies

One set of activities in the Center focuses on the environment. For the past nearly five years, the Center has been coordinating, through the Hazardous Substances Group, a collaborative effort of faculty across MIT dealing with both technical and policy issues. During the past year, the policy element, under the direction of Dr. John R. Ehrenfeld, has expanded into a full-blown set of projects in the Center examining the fundamental relationship of technology and the environment, and, in particular, the roles of businesses as the principal agent of technological change.

This evolving program, which is being called Technology, Business, and the Environment, has been examining environmental management practices through a series of case studies on firms in the chemical, automobile, electronics, and consumer

products industries. The research aims at identifying organizational practices in firms that integrate environmental management into the mainline management and that introduce environmental concerns into product and process design. The early results of the research were publicly introduced through an MIT summer course, *Environmental Management in the 21st Century*, attended by senior environmental managers from firms in the U.S. and abroad.

The MIT Workshop on Business and the Environment held a series of monthly seminars during the year, attended by business and industry leaders, faculty from MIT and neighboring schools, environmental advocates, government officials, and students. These seminars have helped us shape our research and academic agenda and serve as a sounding board for the ideas that are emerging. Attendees have already implemented new practices learned informally at the seminars.

Chemicals in the Environment, a series of four courses developed and taught by the faculty working together in the Hazardous Substances Management Program won this year's MIT Sizer award for the most outstanding contribution to MIT education. These courses provide an interdisciplinary and broad contextual framework in a format available to students from every corner of MIT. They are among the most popular of MIT's natural context courses.

New approaches to setting priorities in the Superfund program, the nation's primary program aimed at cleaning up old hazardous waste dumps, are being developed in a critical study of that program. This study points to better ways of routing the thousands of sites in the pipeline to their clean-up destinations. Improvements promise to achieve higher levels of clean-up and risk reduction, and to enlarge opportunities for emerging technologies.

Professor Nicholas Ashford chaired a key committee of the EPA's advisory group, the National Advisory Committee for Environmental Policy and Technology (NACEPT). Under his direction, the Technology Innovation and Economics Committee published a major critical study dealing with barriers to innovation, entitled "Permitting and Compliance Policy: Barriers to US Environment Technology Innovation."

Large-Scale Systems

Professor Daniel Roos and Dean of Engineering Joel Moses are co-chairing a Committee on Large-Scale Systems. As a result of technological change, technological and socio-technological systems are more complex and of greater scale. Traditional analyses and design techniques are often inadequate to properly understand the behavior of such systems. The Committee on Large-Scale Systems has been formed to explore frameworks and methodologies for large-scale systems. The overall objective is to develop educational and research initiatives at MIT that reflect these different frameworks and methodologies.

Although an initiative of the School of Engineering, the Committee has broad participation outside the School including Jean de Monchaux, Dean of Architecture and Planning, Ann Friedlaender, Professor of Economics, Michael Piore, Professor of Economics, Tom Magnanti, Professor of Management Science, Tom Hughes, Visiting Professor of Science, Technology and Society, and Arthur Steinberg, Associate Professor of Anthropology/Archaeology.

The committee has met on a bi-weekly basis and prepared a series of case studies that examine specific large-scale systems. A retreat is planned for this summer with the objective to begin the development of several new courses that focus on large-scale systems.

EDUCATION

The main educational achievement of the Technology and Policy Program in 1990-91 was the implementation of an outreach program to senior and mid-career professionals in Policy Analysis. We have established a coordinated set of short courses that bring practitioners together with MIT faculty, researchers and students. At present this is based on the traditional one-week summer courses on campus but, as this format is inconvenient to senior managers of technology policy, we expect to inaugurate 2- and 3-day courses, also in the fall and spring, and sometimes on-site with major agencies.

This outreach program has many significant benefits for education at MIT. Most obviously, it provides substantial funding for curriculum development, otherwise virtually unavailable at MIT. More subtly, the interaction with the practitioners is an education for all of us about what the real issues in technology policy are. The contacts also provide good opportunities for student internships.

This year saw increased national and international recognition for the Program. The *US News and World Report*, for example, ran a feature article on the Technology and Policy Program. From this and other visibility, applications have doubled over the last two years and are now eight times the planned class size.

This year also saw the integration of political science into the core curriculum, through the intensive participation of Professor Michael Lipsky.

Professor de Neufville spent the fall on leave as a US-Japan Leadership Fellow, learning about technology policy in Japan. This is part of the Program's continued efforts to define itself internationally.

DANIEL ROOS

Center for Transportation Studies

INTRODUCTION

The Center for Transportation Studies (CTS) is an interdepartmental organization whose objective is to provide an environment in which faculty, students, and staff can work together on transportation issues, many of which are interdisciplinary in nature. Programs of research, education, and industry outreach are supported in part by income from the Center's endowment which was graciously contributed by the UPS Foundation, in part by support from industrial and public sector sponsors, and in part by MIT. These three programs are closely related as we serve the needs of our students, participating faculty and staff, and the transportation industry.

The Center draws on the faculty and staff of MIT to provide programs of interdisciplinary research and education. The vitality of the Center depends on its ability to attract individuals with interests in transportation and representing a wide-ranging set of disciplines that can be applied to the transportation environment. We are fortunate in having over 50 faculty and staff representing all five schools affiliated with CTS. Departments represented are:

Aeronautics and Astronautics, Architecture, Civil Engineering, Economics, Electrical Engineering and Computer Science, Materials Science and Engineering, Mathematics, Mechanical Engineering, Ocean Engineering, Physics, Political Science, Urban Studies and Planning, Sloan School of Management, and the MIT Lincoln Laboratory.

As we enter the 1990s, we find ourselves at a very challenging and exciting time in transportation. We are faced with a number of critical transportation issues around the world.

Among these issues are urban, suburban, and air congestion; an increasingly international environment for trade; infrastructure deterioration; a focus on productivity in both the developed and developing world, with implications for a tighter logistics cycle on an international scale; and the changing face of the transportation industry as a whole, due to deregulation and changing organizational structure.

At the same time, we have the opportunity to take advantage of extraordinary advances in various areas of technology and methodology. Among these are information sciences; communications; mathematical methods and operations research; materials and structures; robotics, automation and remote sensing; and organization and economic theory.

Our challenge in transportation at MIT is to utilize these technological advances to address critical transportation issues.

RESEARCH

Research in transportation is approached through many disciplines at many different levels, and involves all modes of transportation, both passenger and freight, in both the public and private sectors. During the past academic year, 129 sponsored, seed, and unsponsored projects were listed in the Center's **Current Research Projects in Transportation at MIT** (available upon request).

Categories of research include: Logistics and Network Analysis, Rail and Trucking, Air Transportation, Computer Systems, Motor Vehicles, Health and Safety, Ocean Transportation, Urban and Regional Transportation Planning, Labor Issues, and Infrastructure Maintenance and Rehabilitation.

Annual sponsored research volume for the Center this year continued its long-term growth to a level in excess of \$3 million.

Major Research Initiatives include:

1. The University Transportation Centers (UTC) Program
(Principal Investigator: Mr. Thomas Humphrey)
2. The program in Intelligent Vehicle Highway Systems
(Principal Investigators: Professors Joseph Sussman, Daniel Roos, Moshe Ben-Akiva; Mr. Humphrey; and Mr. Milan Vlahinac, Lincoln Labs)
3. Air Traffic Control Research
(Principal Investigator: Professor Jin Kong)
4. Freight Logistics Program
(Principal Investigator: Professor Yosef Sheffi)
5. Rail Research Group - Association of American Railroads
Affiliated Laboratories (AAR) Program
(Principal Investigators: Professor David Wormley; Mr. Carl Martland)
6. Transit Program
(Principal Investigator: Professor Nigel Wilson)
7. Airport Security Research
(Principal Investigator: Professor Lee Grodzins)
8. Management Information Systems in Transportation
(Principal Investigator: Dr. Amar Gupta)

This year we highlight some of the current rail research activities at the Center.

Rail research at MIT has a long and distinguished history. During the 1970s, the MIT Research Program in Railroad Operations and Economics conducted a total of 28 research projects for a dozen sponsors resulting, among other things, in the development of a major model for railroad service planning, and in a savings of more than \$3 million for the Boston & Maine. During roughly that same time, the Vehicle Dynamics Laboratory approached the industry from a technological viewpoint, conducting research on how to improve the performance of ground transportation. To provide a continuing framework for what became, through those two programs, a productive long-term relationship with the railroad industry, the Association of American Railroads Affiliated Laboratories Program was established at MIT in the 1980s. And now, as the 1990s begin, the tradition of railroad research continues with over 30 active projects in technology, economics, competition, equipment maintenance, labor costs, logistics, and industrial relations. Four of those projects supervised by Carl Martland, promoted this year to Senior Research Associate, are listed below:

Analytic Techniques for More Effective Rail Scheduling

Burlington Northern Railroad

Methods for deciding when and where rail should be relayed on a complex rail freight network.

Total Right-of-Way Analysis Costing System

Association of American Railroads

Methods for addressing the gap between the extensive amount of rail research that has been done on rail track maintenance and the use of that data by people in the field.

Evaluating the Effects of Heavy Axle Loads

Association of American Railroads

Developing tradeoffs between productivity benefits on larger car loads and the maintenance implications of heavy axle loads.

The Future of Railroads in New England

New England Transportation Consortium

An investigation of what New England might do, as a region, to help relieve congestion and highway deterioration by increasing rail traffic.

Over the years, the Rail program of the Center has been prototypical of our research program, in that results of direct use to the industry have been produced, while involving large numbers of students who subsequently work and advance in the rail industry.

EDUCATION

MIT offers advanced degrees in various areas of transportation at the masters and doctoral levels. Almost 100 subjects are offered in transportation and related fields, including systems methodology, operations research, social science, and management. Over 60 students are currently working toward masters or doctorate degrees.

The Center administers the interdepartmental **Master of Science in Transportation** program. Its graduates have gone on to careers with carriers, operating agencies, shippers, consulting firms, and government, and into doctoral programs at MIT or elsewhere. Students in the MST Program take core subjects in transportation systems analysis and transportation economics. Then, concentration in areas such as logistics, urban transportation, air transportation, ocean transportation, etc., are available. Professor Nigel Wilson chairs the MST Program.

Through the University Transportation Centers program, we have a new fellowship program as of September 1990. These fellowships are intended to attract high quality students to the transportation field for graduate work. With the availability of these fellowships, CTS embarked on a major publicity campaign to attract new students, including a mailing to the American Society of Civil Engineers (ASCE) Student Chapter members who are in the junior and senior class across the nation. We were gratified to see higher quality candidates as well as a doubling in the number of applications, allowing us to be even more selective than we have been in the past. In September 1991, ten UTC fellowship holders will join our student body.

In an effort to reach MIT undergraduates who might be interested in graduate study, but who have not yet had the chance to get acquainted with the transportation field, this year, for the second year, the Center funded six undergraduate research fellowships. Through these, MIT undergraduates work with faculty and staff on transportation research projects.

Also, CTS offers several summer research fellowships to juniors with interest in transportation from schools other than MIT. The idea is to give these students a research experience and to acquaint them with our graduate program in the transportation field.

Double Master's Program

In a major educational initiative, CTS joined with the Sloan School of Management to develop a double Master's program, which will cover the spectrum of transportation and logistics issues.

In response to escalating demand, on the part of both shippers and carriers, for management professionals with specific technical skills in transportation and logistics, MIT has introduced a double Master's program which will cover the spectrum of transportation and logistics issues. The two-year program leads to a Master of Science in Management, administered by the Sloan School of Management, and a Master of Science in Transportation, administered by the Center.

Recipients will be prepared for work with both shippers and carriers on planning, engineering, controlling, and managing the flow of materials and parts from suppliers to plants, and of finished goods from plants to consumers. These logistics operations, which are quickly becoming some of the most important elements of business for the 1990s and beyond, include such functions as transportation management, warehousing, order processing, inbound flow control, inventory management, and packaging. They also overlap heavily with other functions such as purchasing, production scheduling, and marketing.

The curriculum consists of a full 24-month program, including four academic semesters and two summer sessions. Students must satisfy the course requirements of both the Sloan Master's Program and the Center's Master of Science in Transportation Program, in addition to taking some electives related to logistics.

The master's thesis is based on research performed in conjunction with an internship at a sponsoring organization during the first summer term. The sponsoring organizations may include carriers--such as truck lines, railroads, airlines, and ocean carriers--and the transportation/logistics divisions of manufacturers, retailers, distributors, and other participants. The thesis will reflect a year-long research effort formulated during the internship on a topic of interest to the sponsoring firm, and the student will have a thesis monitor at the company, in addition to a faculty adviser. The written thesis document will be completed during the second summer of the program.

United Parcel Service Fellowships

CTS continues to provide fellowship support for particularly able students at the MST and doctoral levels funded by the United Parcel Service (UPS) Foundation. The doctoral fellowship is awarded to a student who plans a doctoral dissertation in the transportation field. The competition reflects the breadth of transportation interests at MIT. For example, in the most recent competition, we attracted applications for students from the Departments of Civil Engineering, Ocean Engineering, and Urban Studies and Planning; the Operations Research Center; and the Sloan School of Management. For 1990/91, the doctoral award was split between Isam Kaysi and Garrett van Ryzin. For 1991/92, Tsippy Lotan was awarded the UPS Doctoral Fellowship. In addition, for 1990/91, we awarded fellowships to three particularly able MST students, Rick Halvorsen, Lucy Jen, and Yu-Ting Yuo. For 1991/92, the MST fellowships will be awarded in September.

Further, we continued to provide partial support for needy graduate students in transportation.

Theses

This year, the Center produced a valuable research resource. All MIT transportation graduate theses from 1980 through the present are listed in a bound document that will be widely distributed. It is hoped that this will serve a useful function for the transportation community. It is available upon request to the Center.

INDUSTRY AFFILIATE ACTIVITIES

The CTS Industry Affiliates Program, established in 1981 to develop relationships between MIT and the transportation industry, is an important component of the education and research programs of the Center. This year, the program continued to grow with the addition of three companies: USX, PPG Industries, and Goodyear Tire Company. Continuing members are: American President Lines, Burlington Northern Railroad, Campbell Soup, Conrail Corporation, CSX Transportation, Digital Equipment, Dow Chemical Company, Du Pont, Federal Express, General Motors Research Laboratories, Gillette, IBM, Johnson and Johnson, The 3M Company, Norfolk Southern, Rockwell International, Ryder System, Sea-Land, Southern Pacific Transportation, Union Pacific, and United Parcel Service.

The success of the Affiliates Program has helped to give the MIT Center for Transportation Studies a unique place among the dozen or so research centers in transportation at American universities. The program has provided important opportunities for MIT faculty and students. Since 1985, the Affiliates Program has attracted top leaders in transportation to high level forums to discuss emerging policy issues in transportation. These forums give the faculty access to transportation decision makers at the highest level. In addition to these senior level forums, many mid-level executives have been attracted to MIT

to participate in technical seminars, clinics, and summer subjects developed by the Affiliates Program. These events give MIT faculty a chance to work with transportation executives on real world problems. The Affiliates Program has opened up to faculty and students at MIT a research domain in transportation and logistics whose problems are meaningful, complex, and intellectually challenging.

This past year, for the first time, a CTS Affiliate joined the School of Engineering Internship Program with an eye to attracting undergraduates to careers in transportation. CSX Transportation had one student working in Jacksonville, Florida, in the Summer of 1990, and has two students in the Summer of 1991.

In keeping with the goals of the Affiliates Program, each year an affiliate firm hosts a day-long meeting for the other affiliates on a subject of mutual concern. This past October, approximately 60 transportation executives met at The Peabody Hotel in Memphis, Tennessee, to focus on "The Effective Use of Time: A Component of the New Logistics." The meeting was hosted by Federal Express. In a world increasingly concerned with productivity and competitiveness, the effectiveness of transportation service is key. This event focused on this issue. Keynoted by Fred Smith, founder and Chief Executive Officer of Federal Express, the group was also addressed by a number of Federal Express executives and customers. MIT faculty addressing the group were Professor Sussman who discussed the CTS Program and the challenge the transportation world faces; Professor Sheffi who discussed the Logistics Information Center concept--the use of information and communications systems to address the increasing needs and opportunities confronting the logistics professional, while at the same time operating within a context of shrinking economic and human resources; and Professor Magnanti discussed recent research into reducing cycle time in manufacturing, drawing on studies being done in the Leaders for Manufacturing Program and the International Motor Vehicle Program, both at MIT and on research at Motorola, Boeing, and the Harvard Business School. Also, Gerard McCullough chaired a panel on improving customer service through third party logistics.

The highlight of this Affiliates' Day event was a tour of the Federal Express Super Hub, with an opportunity to observe the "Midnight Sort" at this facility.

Next year's meeting will be hosted by Union Pacific, at their Omaha, Nebraska Headquarters.

Summer Executive Program

Last summer and again this summer, we will present the very popular intensive one-week seminar taught by Professor Sheffi on **Logistics Analysis for Carriers and Shippers**. The seminar is designed to help shippers become increasingly sophisticated about logistics, and to help carriers better understand demands by shippers which are based on logistics analysis. This subject is at the heart of the Affiliates Program and attracts an international group of transportation specialists.

Technical Seminars

The Industry Affiliates Program sponsors technical seminars for member firms. This year, two seminars were offered.

In December 1990, a seminar on "Advances in Distributed and Parallel Computing in Transportation" was offered by Professor Steven Lerman, formerly director of MIT's Project Athena, and currently director of the Intelligent Engineering Systems Laboratory (IESL) and the Center for Educational Computing Initiatives (CECI).

This event focused on exploring the state-of-the-art in distributed and parallel computing. The goal of the seminar was to familiarize practicing professionals within transportation companies and major shippers with existing and emerging options for delivering information services.

Distributed computing involves the interconnection of diverse computers through local and wide-area networks to provide a range of services that no single computer can deliver. This approach allows companies to diversify the manufacturers whose equipment they use while still preserving the ability to access data throughout their organizations. A general review of distributed computing and a case study

of MIT's campus computing system was presented. The use of distributed computing to coordinate activities that are spread across large geographical areas, a fundamental characteristic of transportation enterprises, was also discussed.

In April 1991, a seminar was held on "Application of Network Optimization," chaired by Professor Thomas Magnanti, Co-Director of both the Operations Research Center and Leaders in Manufacturing Program. With recent advances in this field, this technical seminar was quite timely. The seminar focused on modeling approaches and uses of network optimization in the transportation, telecommunication, and manufacturing industries as well as recent developments concerning emerging topics such as network optimization on parallel computers, freight flow planning, advances in operations research, and computational issues.

STAFF

During this year, Fred Salvucci joined the research staff of the Center and the Department of Civil Engineering as a Senior Lecturer. Mr. Salvucci served for 12 years as the Secretary of the Executive Office of Transportation and Construction for the Commonwealth of Massachusetts, a cabinet appointment. He was at the very center of major policy and implementation issues in transportation and brings to the Center a unique set of capabilities for our research and teaching program. This past year he taught a subject entitled, "Transportation Policy in the Boston Metropolitan Area, 1956-2000," and further laid the groundwork for an active research program in transportation policy.

THE TRANSPORTATION COMPUTING LABORATORY

Under the direction of Professor Sheffi, the Transportation Computing Laboratory (TCL) is the cornerstone of computing at CTS, supporting a high level of academic and research work. The TCL supports all transportation subjects and the individual research and academic work of graduate and undergraduate students in transportation. With some additional generous support from the UPS Foundation, the TCL enjoyed substantial growth during this past year.

Apple Macintosh users benefited from the purchase of three Macintosh IICI's and a Macintosh IISI. These new Macs doubled the number of available workstations while providing increased storage capacity, speed, and color. For MS-DOS users, the TCL acquired a Northgate 80386/33 MHz computer, increasing the number of 386-class machines in the Lab to seven. A Dell 286-based machine was also added. All the DOS-based computers in the Lab now feature 286 or 386 processors. The TCL adopted a minimum configuration for our 386-class PCs: VGA color monitors, at least 4 MB of RAM, a math coprocessor, and a mouse. To meet this standard, most of the computers required upgrades; all of the TCLs 386 computers now meet this standard.

This year saw the introduction of geographical information systems (GIS) software into the TCL with the installation of Arc/Info and TransCAD. New spreadsheet, database, and presentation tools were added. To accommodate users with computationally intensive tasks, the TCL purchased a Digital DECstation 3100, which features a RISC architecture. The machine will be connected to the campus network, fostering connectivity throughout MIT and beyond.

TRANSPORTATION RESEARCH BOARD MEETING

Each January, the Transportation Research Board (TRB) meets in Washington. This is probably the major professional meeting for the transportation community, attended by more than 5000 people. Professor Joseph Sussman, director of the Center, serves on TRBs Executive Committee. The Center for Transportation Studies has always had a high profile at this meeting. Numerous papers are given by faculty and staff, and we are active on many committees as well. We host a reception for MIT alumni which is traditionally well attended.

This year, we highlight the participation of CTS students in this meeting. As in the past years, about 30 students attended this meeting with their travel subsidized by the Center. The students have given us very positive feedback on this professional experience. They gain a great deal through this opportunity to attend sessions and to meet and interact with highly regarded transportation specialists from around the world. The experience also leads to the development of a real esprit de corps within the student body.

SEMINARS ON STRATEGIC PLANNING AND DECISION-MAKING

In July 1990, January 1991, and June 1991, the Center, in conjunction with the John F. Kennedy School of Government at Harvard and the John A. Volpe National Transportation Systems Center, offered two and one-half day seminars for senior transportation executives for the US Department of Transportation in groups of twenty-five.

These seminars were organized to enhance the department's effectiveness in implementing the national transportation policy--a product of the most extensive policy planning effort ever conducted in the US in transportation--and to improve its ongoing executive development program. By giving executives the chance to discuss intermodal approaches to national transportation policy issues, these seminar helped improve their ability to use strategic planning in addressing transportation needs, and to broaden their understanding of public policy decision-making. The seminars focused on multimodal intercity passenger transportation issues with an emphasis on policy formulation.

The Department of Transportation evaluation of the seminars were quite positive, and it is expected these will be continued in the future.

LUNCHEON SEMINAR SERIES

Every year, the Center sponsors this series featuring transportation experts from the public and private sectors, and from academia, discussing current issues in the transportation field. Open to the public-at-large, the seminars draw an audience made up of students and faculty from the Institute, and the local business, government, and academic communities. Attendance has grown substantially over the last several years as this monthly event has gained prominence on the MIT calendar and that of the local transportation community. A broad spectrum of topics were covered by a distinguished group of speakers as follows: Mr. Frederick Salvucci, Secretary of Transportation, Massachusetts Executive Office of Transportation and Construction; Mr. James Drogan, Industry Consultant, International Business Machines Corporation; Dr. Robert E. Paaswell, Director, University Transportation Center, Region Two, Institute for Transportation Systems, The City College of New York; Mr. Louis Thompson, Railways Adviser, Transportation Division, The World Bank; Mr. Clifford Sayre, Vice President, Materials, Logistics, and Services, E.I. du Pont de Nemours and Company; Professor Daniel Roos, Director, Center for Technology, Policy, and Industrial Development, Japan Steel Industry Professor, MIT; Mr. Roland J. Mross, Deputy Administrator, Urban Mass Transportation Administration, US Department of Transportation; and Professor Alan Altshuler, Director, Taubman Center for State and Local Government, Ruth and Frank Stanton Professor in Urban Policy and Planning, The John F. Kennedy School of Government, Harvard University.

SUMMER SUBJECTS

Last August, for the eighth consecutive year, a one-week summer course was offered by Professor Nigel Wilson in **Public Transportation Service and Operations Planning** and attracted an international audience. This subject was offered in July 1990 in Australia, and will be offered on campus in the Summer of 1991.

In June, Professor de Neufville and Professor Amedeo Odoni offered, for the third time, a subject in "Airport Systems: Strategic Planning and Detailed Design." It continues to be very attractive to the professional community.

Transportation will continue to be a vital field and a major factor in economic development. Many of the major policy issues of the 1990s, including congestion, infrastructure, productivity, and international competitiveness have transportation as a critical component. Technology, systems analysis and economics, and management and institutional factors are all important points of view for the study of transportation. We are fortunate to have here at MIT a talented faculty representing each of these approaches as we face the challenges and opportunities in the transportation arena.

A PERSONAL NOTE

Earlier this year, I indicated to Dean Joel Moses that I would like to return to full-time teaching and research. The Dean graciously granted this request, and on August 31, 1991, I will step down as Director of the Center. I have enjoyed the past five-plus years, and am grateful for having had the opportunity to serve. I particularly enjoyed the opportunity to interact with so many faculty, staff, and students around the Institute. We are blessed with a dynamic and exciting field, and we have many opportunities to continue to contribute to the international transportation community in the public and private sectors.

I wish my successor, Professor Yosef Sheffi of the Department of Civil Engineering, the best of luck as he assumes his new duties on September 1, 1991. He has been very active in the programs of the Center. Professor Sheffi has served for the past six years as head of the Transportation Systems Division in the Department of Civil Engineering. In his role as TSD head, he has developed and brought to fruition a variety of research and education programs. He brings to the position of CTS director excellent credentials in teaching and research, as well as well-known fund raising abilities. I am confident Yossi will make an outstanding director and look forward to working with him.

Again, let me say that I have enjoyed working with the transportation community both inside and outside MIT during my term as director, and certainly expect to stay in close contact with the programs of the Center in the future. I do appreciate your support and help, and I am sure you will extend the same to Yossi as he assumes his new responsibilities.

JOSEPH M. SUSSMAN

Laboratory for Computer Science

The MIT Laboratory for Computer Science (LCS) is an interdepartmental laboratory whose principal goal is research in computer science and engineering.

Founded as Project MAC in 1963, the Laboratory developed one of the world's earliest time-shared computer systems. This early research on the Compatible Time Sharing System (CTSS) and its successor, MULTICS, made possible innovative developments such as the writing of operating systems in high level programming languages, virtual memory, tree directories, on-line scheduling algorithms, line and page editors, secure operating systems, concepts and techniques for access control, computer-aided design, and two of the earliest computer games, space wars and computer chess.

These early developments laid the foundation for the Laboratory's work in the 1970's on knowledge based systems -- for example, the MACSYMA program for symbolic mathematics -- natural language understanding, and (with BBN) the development and use of packet networks. During this same period, the Laboratory developed theoretical results in complexity theory and linked cryptography to computer science through concepts and algorithms for public encryption (RSA). In the late 1970's, Project MAC, renamed as the Laboratory for Computer Science (LCS), embarked on research in clinical decision making, on the exploration of cellular automata at the borderline between physics and computation, and on the social impact of computers. At the same time, it began two major research programs in distributed systems and languages and in parallel systems. These led to the notion of data abstractions and the CLU language, the ARGUS distributed system, the dataflow principle and associated languages and architectures of parallel systems, local area ring networks, program specification and workstation development, where the Laboratory contributed the earliest UNIX ports and compilers, and the Nubus architecture, now used in commercial computers such as Apple's Macintosh II. This research has also led to the X Window System, a computer intercommunication and user interface approach, developed together with Project Athena and widely used by industry.

The Laboratory's current research falls into four principal categories: Parallel Systems; Systems, Languages, and Networks; Intelligent Systems; and Theory. The principal technical goals of these four categories are as follows:

With *Parallel Systems*, we strive to harness the power and economy of numerous processors working on the same task. Research in the area involves the analysis and construction of various hardware architectures, programming languages and operating systems that yield, over a broad set of applications, cost-performance improvements of several orders of magnitude relative to single processors. This research is likely to affect most of tomorrow's machines, which we expect to be of the multiprocessor variety -- not only because of potential cost performance benefits, but also because of the natural, yet unexploited, concurrency that characterizes contemporary and prospective applications from business to sensory computing.

In the areas of *Systems, Languages and Networks*, our objective is to provide the concepts, methods, and environments that will enable heterogeneous computers, each working on different tasks, to communicate efficiently,

conveniently, and reliably with each other in order to exchange information needed and supplied by their respective programs. Such communication may involve, beyond conventional electronic mail and file transfer, the communication of programs in one environment with programs in another, perhaps different, environment; storage in persistent object-oriented repositories and the sharing of structured data among such programs; interactive use of high-quality video and sound together with text and graphics; and the use of an information infrastructure consisting of common computer and communication resources. This research is also expected to have a broad impact on future systems because virtually every machine will be connected to some network.

In the *Intelligent Systems* area, our technical goals are to understand and construct programs and machines that have greater and more useful sensory and cognitive capabilities so that they may communicate with one another and with people, toward useful ends. Examples include interactive machine understanding of spoken messages, systems that can learn from practice rather than by being explicitly programmed, and programs that reason about clinical issues and help in clinical decision making. We expect tomorrow's intelligent systems to be easier to use than today's programs, across a broad front of applications.

Taken together, these three thrusts in parallel, networked and intelligent systems define the Laboratory's overarching goal: Better human communication with and development of tomorrow's computer systems, which will consist of multiprocessors interconnected by networks, and perhaps some day by national network infrastructures, as ubiquitous and as important as today's telephone and highway infrastructures.

In our fourth category of research, *Theory*, we strive to understand these systems and discover the fundamental forces, rules, and limits of computer science. Accordingly, theoretical work permeates many of our research efforts in the other three areas; for example, in the pursuit of parallel algorithms and in the study of fundamental properties of idealized parallel architectures and fault tolerant computer networks. Theory also touches on several predominantly abstract areas, such as the logic of programs, the inherent complexity of computations, and the use of cryptography and randomness in the formal characterization of knowledge. The impact of theoretical computer science upon our world is expected to continue its past record of improving our understanding and helping us to pursue new frontiers with new models, concepts, methods, and algorithms.

Research highlights during the reporting period are as follows:

1. The Laboratory's Spoken Language Systems Group, headed by Dr. Victor Zue, has developed the Air Travel Information System (ATIS), a speaker independent interactive spoken language understanding system. ATIS accepts continuous human speech and can handle English sentences and phrases as long as they involve booking airline tickets and all that goes with that process.

Building on this success, we have begun exploration of what we call international interpretive telephony. Users of such a telephone would speak in their native tongue using a limited vocabulary of a few hundred words in a narrow domain of discourse, as for example, in planning appointments, visits and travel. Each sentence would be translated through an intermediate language (I.L.) to the language of the other party. It would also be simultaneously translated back from I.L. to the original language to ensure

that the system "understood" what was said. To date, we have secured informal partnerships in Europe and Japan for the purpose of beginning this new research activity.

2. Professors David Clark and David Tennenhouse along with their colleagues have begun research on advanced networks and workstations aimed at handling high speed video information along with sound and text. Novel processing-on-the-fly methods are being explored in this area, in addition to the more traditional retrieve-process-and-store techniques. In addition, this research focuses on new ways for handling information across very large networks.

3. In the multiprocessor area the Laboratory took delivery from Motorola of a prototype dataflow machine developed jointly with that company. The machine will serve as a testbed for continued program development and for finalizing the Laboratory's revised dataflow machine design. The latter is an architecture based on the use of RISC processor chips, augmented by a few highly optimized capabilities for handling the rapid context switching requirements of dataflow multiprocessing. During this period considerable progress was also made on the Laboratory's three other multiprocessor architectures -- Alewife (Professor Anant Agarwal), the J-Machine (Professor William Dally) and the NuMesh (Professor Stephen Ward). Prototypes of the first two machines are expected to begin operating within the coming year. A small prototype of the NuMesh is now operational.

During this reporting period, the Laboratory's Distinguished Lecturer Series included presentations by James Flanagan, Director, Center for Aids for Industrial Productivity, Rutgers University; Leslie Valiant, Professor, Harvard University; H. T. Kung, Professor of Computer Science, Carnegie-Mellon University; Frances E. Allen, IBM Fellow, IBM T. J. Watson Research Center.

Dr. Lynette Hirschman joined the Laboratory as a Principal Research Scientist in the Spoken Language Systems Group and Dr. Yuli Zhou became a Research Associate in the Computation Structures Group. Departures included that of Professors Leo Guibas, who went to Stanford, and Research Associate Jonathan Young.

Changes in the administrative staff included the arrival of Ms. Anne Wailes, who joined us as Administrative Staff Assistant to the Director, and the departure of our Information Manager Ms. Paula Vancini.

The Laboratory is organized into 15 research groups, an administrative unit, and a computer service support unit. The Laboratory's membership includes a total of 405 people -- 108 faculty and research staff members, 37 visitors, affiliates, and postdoctoral associates, 34 support staff, 165 graduate students, and 61 undergraduate students. The academic affiliation of most of the Laboratory's faculty and students is with the Department of Electrical Engineering and Computer Science (EECS).

About one half of the Laboratory's funding comes from the U.S. Government's Defense Advanced Research Projects Agency. The Laboratory is also funded by and has extensive links with industrial organizations. These include partnerships for the construction of major hardware systems, consortia for the development and maintenance of standards, such as X Windows, and joint studies on research areas of common concern.

Laboratory for Electromagnetic and Electronic Systems

The mission of the Laboratory for Electromagnetic and Electronic Systems (LEES) is to be the focus for research and teaching in electric energy from its production through its processing to its utilization, and in electromechanics from the macroscopic through the microscopic to the molecular levels. Electric energy and electromechanics are defined broadly to include power systems monitoring and operation; automatic control; power electronics; high voltage engineering; and conventional, continuum and biological electromechanics.

During the last year, the laboratory suffered the loss of its director, Professor James Melcher. Professor Melcher was considered the father of continuum electromechanics, and was a prolific writer, having authored or co-authored five textbooks. Shortly before his death, he and Professor Markus Zahn produced a series of videotaped demonstrations to supplement his latest book, **Electromagnetic Fields and Energy**, co-authored with Professor Herman Haus.

Subsequent to Professor Melcher's death, Dean Joel Moses appointed a committee to review the mission and future of LEES. The members of the committee were Professors Thomas H. Lee (chairman), Alan Grodzinsky, Kent Hansen (NE), Herman Haus, John Kassakian, and Jeffrey Lang. The report submitted to Dean Moses in May reaffirmed the importance of LEES to MIT's role in engineering education and research, and recommended a number of initiatives designed to improve the laboratory's effectiveness in carrying out its mission. In June, Professor Kassakian was appointed Director and Professor Lang was named Associate Director of LEES.

BIOLOGICAL ELECTROMECHANICS AND PHYSIOLOGY

Electromechanics of Connective Tissues and Membranes

Professor Grodzinsky and his group have continued their study of the effects of physical forces on the growth, remodeling and repair of connective tissues, in collaboration with Orthopaedic Research Laboratories at the Massachusetts General Hospital (MGH) and the Shriners' Hospital, Tampa. This work was recently presented at special invited lectures in Weisbaden, Tokyo, Bern, and at the Orthopaedic Research Society. Recent experiments using cartilage specimens in organ culture have shown that cartilage cells are very slow to recover from large static compressions, an *in vivo* joint loading condition that also suppresses cartilage tissue assembly and repair. Work with MGH is aimed at enhancing cartilage repair using protein growth factors in combination with low frequency dynamic compression, which has been found to stimulate synthesis of cartilage tissue. A new collaboration with industry focuses on identifying the mechanisms by which abnormal joint loading may induce cell production of enzymes that cause cartilage destruction in osteoarthritis.

Professor Grodzinsky, Dr. Eliot Frank, in collaboration with Brigham and Women's and the West Roxbury VA Hospitals are continuing their study and development of a surface sensor probe for nondestructive detection of cartilage degeneration that occurs at the earliest stages of osteoarthritis (OA). Interdigitated electrodes deliver small currents to the tissue over a spectrum of frequencies and surface wavelengths; the resulting mechanical surface stress may be used to image and quantify focal tissue changes associated with OA degeneration. New grant awards from NSF and the Veteran's Administration have initiated thesis research on the design fundamentals and development of a useful clinical diagnostic sensor. A new collaboration with Professor Stephen Senturia (MTL) focuses on microfabrication of a silicon-based sensor chip for the probe. Such a chip should also enable a wide range of new studies on the molecular electromechanics of biological and synthetic materials.

The possibility of developing a cartilage substitute material is one of the long term goals of research involving culture of cartilage cells in a gel medium. Recent studies have shown that after several weeks in culture, a cartilage-like matrix is developed having functional mechanical and electromechanical properties that mimic those of native, intact tissue. Further, cells in gel culture appear to respond to mechanical forces in a manner similar to that of native cartilage. Current research focuses on regulating the quality of newly synthesized matrix, and understanding the mechanisms of regulation at the cellular level.

Professor Grodzinsky, Dr. Adi Shefer, and their students are continuing research on hydrogels and membranes for protein separations and feedback-regulated drug delivery, in collaboration with the Biotechnology Process Engineering Center at MIT. A patent just awarded documents several techniques by which applied electric fields can modulate membrane permeability to proteins and simultaneously augment separations using electrophoretic and electro-osmotic forces.

Professor Martha L. Gray and her group have continued their efforts to examine the role of physical forces in connective tissue growth and development. A system in which neonatal cartilage will grow in vitro has been established and fully characterized. In collaboration with molecular biologists at Children's Hospital current studies are directed at investigating the effect of physical factors on growth rate, tissue composition, and gene expression. For example, experiments investigating the effect of changing the pH of the culture medium demonstrated a dramatic enhancement of growth rate with increasing pH. The enhancement in growth was affected by both increases in rates of cell division (an effect that has been observed in many systems) and increases in extracellular matrix production. These results may have implications regarding the control of matrix synthesis in states of tissue growth and repair.

In collaboration with Professor Lee Gehrke (HST), studies are underway to evaluate the coupled effects of mechanical forces and interleukin-1 (IL-1) on cartilage metabolism. Interleukin-1 is a cytokine which is involved in inflammatory processes and, in particular, is believed to be involved in the mechanism of cartilage degradation in rheumatoid and, perhaps, osteoarthritis. With available molecular biology technologies a variety of IL-1 proteins can be made readily, including several IL-1 receptor antagonists, thus providing the tools for investigating mechanisms of IL-1 and force mediated cartilage remodeling, and potentially providing a means for rational design of therapeutics to block the degradative processes in arthritis.

Research continues on developing nondestructive NMR techniques for evaluating functionally relevant features of cartilage tissues with the collaboration of Dr. Burstein of Beth Israel Hospital. A recently submitted manuscript describes the use of sodium NMR for estimating tissue fixed charge density (FCD), and the ability to observe changes in tissue charge following a variety of interventions. Recent results include observing increases in fixed charge density (but constant total fixed charge) following tissue compression, and decreases in FCD during exposure to enzymes which degrade the tissue. We are also using NMR methods for measuring self-diffusion and diffusive permeability of small solutes. The extension of these methods to imaging modalities offers the potential of early and non-invasive monitoring of cartilage disease.

Working together with Professor Senturia initiatives have focused on the development of integrated devices for medical and biological applications. A prototype flow cytometer has been constructed which includes transparent viewing windows, so the device may be mounted on a standard microscope; integrated waveguides to achieve multi-axis excitation and detection; and a means for hydrodynamic focusing to ensure that cells pass through the flow chamber single file along a single trajectory. Future plans include extending this device to include pumps, valves, and optical sensors. This device will establish the feasibility of developing integrated systems for biological sensing and processing applications using silicon-based technologies.

Electron Irradiation Research

Mr. Kenneth Wright continues to provide physics input to the MIT-Lahey Clinic Radiotherapy Program which started as a joint project in 1949. Part of the physics aspect of the program provides development of improved techniques for the application of megavolt x-rays and electrons to the clinical treatment of patients, and the dosimetry for treatment and long term evaluation of conventional and new techniques.

Dr. Chathan Cooke and Mr. Wright have used electro-acoustic methods for studying charge distribution and the resultant electric fields and potentials produced by high doses of electrons injected into certain electron trapping solid dielectrics such as PMMA (Lucite, Plexiglass, etc.). The presently recommended dosimetry technique for radiotherapy is to use water and solid phantom materials including PMMA in conjunction with ionization chambers. Reports of ion chamber measurement errors due to electron trapping in PMMA phantoms have appeared in the literature without evaluation of the actual electric fields and potentials produced by charge trapping. Mr. Wright and Dr. Cooke have refined the electro-acoustic measurement techniques to enable the measurement of electron trapping distributions at clinical dose levels immediately following electron injection, and also as a function of time for long term decay after injection.

An NSF sponsored study of water purification by electron irradiation in the presence of polymer is being undertaken by Professor Edward Merrill (Ch.E.) and Mr. Wright. The project has been developed to eliminate organic contaminants using trace amounts of benzene and chlorobenzene as model contaminants similar to other cyclic organic contaminants such as PCB mixtures found in water supplies. The basic concept is to irradiate the contaminants in trace amounts in water in the presence of a polymer which will absorb the decomposition products and form a gel. This gel is then removed by filtration. To study the effects of dose rate, Mr. Wright has worked with Professor Merrill's graduate and UROP students to increase electron beam dose rates by one to two orders of

magnitude over values previously used in the facility.

CONTINUUM ELECTROMECHANICS

An Electric Power Research Institute (EPRI) sponsored project supervised by Professor Markus Zahn on flow electrification in transformers has been extended to include the effects of temperature and moisture dynamics. The recently patented Absolute Charge Sensor (ACS) is being used in testing of electrification effects in various transformer components and will be used on an operating transformer in tests directed by EPRI contractors. A number of journal and conference publications on this work have or will be published, including a review article in the *IEEE Transactions on Electrical Insulation* special issue for the Conference on Electrical Insulation and Dielectric Phenomena.

Absolute charge sensors have also been supplied to a few automotive suppliers for electrification measurements in automotive fuel systems. To meet industry needs in understanding the fundamental physics as well as developing laboratory measurement methods of flow electrification, Professor Zahn offered an MIT Summer Session course entitled "Electrostatic Charging in Power Apparatus and Fuel Transfer Systems". This course was also presented to Ford and General Motors. The Society of Automotive Engineers (SAE) Electrostatic Task Force is drafting a standard for flow electrification measurements which specifically refers to the use of the ACS. MIT measurements of flow electrification by graduate student Andrew P. Washabaugh in the Couette Charger Facility have shown the strong dependence on temperature and moisture level in transformer oil and contacting pressboard. New sensors that continuously monitor temperature, moisture content, and dielectric properties in oil and pressboard have been designed and have been installed in our flow electrification measurement facilities. Moisture measurements have been correlated to new mass-transfer analysis of the transfer of moisture between paper and oil developed by graduate student Philip von Guggenberg. It appears that the transient dry zone at the paper/oil interface when moisture is driven from paper to oil may be a factor in transformer failures due to flow electrification.

Professor Zahn has also been studying the pumping of magnetic fluids in traveling wave magnetic fields and has developed an analysis that includes the effects of fluid spin fields. This spin results in fluids that have internal angular momentum. By including the complete coupling of fluid convection and magnetic particle spin on the magnetization characteristic, together with the resulting magnetic force on the fluid driving the flow, it is hoped to predict and understand the anomalous behavior under certain operating conditions where magnetic fluid is pumped in the direction opposite to a traveling wave of magnetic field. Professor Zahn is a member of the International Steering Committee of the Sixth International Conference on Magnetic Fluids to be held in Paris in July, 1992, where this work will be presented.

ELECTROMECHANICS

This year the International Conference on Electric Machines was held at MIT under the chairmanship of Professor James Kirtley. This conference has been held biennially since 1974, but always in Europe. This was the first time it has been held in the United States. Over 320 scholars in the field of electric machinery participated, and about 240 papers in the field were presented.

Electric Machinery

In cooperation with the McGill University, Professor Lang and Dr. Stephen Umans have developed a high-torque-low-mass motor for robotics applications. Initial tests of the motor indicate that its capabilities exceed those of existing motors by a significant margin. This should permit the motor to be deployed on a homomorphic robot arm in a direct-drive capacity.

Professor Lang, Dr. Umans and their students have continued their research on the detection of failures in electric machines. Using a variety of model-based estimation techniques they have demonstrated the ability to detect such failures as broken rotor bars in induction motors and disrupted cooling of permanent-magnet synchronous motors. They have now joined their efforts with those of Mr. Wayne Hagman and Professor Richard D. Lyon (ME) to develop a failure detection system for motor-operated valves in nuclear power plants.

With support from the Leaders for Manufacturing program, and with matching industrial support, Professors Lang, Kirtley, Dr. Tabors and their students have studied the computer-aided design of electric machines. The novelty of their research is that the design system under development incorporates a broad synthesis algorithm, and specifically addresses the manufacturability of the electrical machines. For every candidate electrical machine which is synthesized, its cost, quality and schedule of manufacturing is computed, just as are the traditional figures of merit

such as power, size and efficiency. Design optimizations based on manufacturing merit as well as electromechanical merit then follow easily. To date, several versions of the design system have been developed for different electric machines, and these are being tested in industrial settings.

Superconducting Generator

The superconducting generator project is proceeding under the direction of Professors Kirtley and Joseph Smith (ME) with support from EPRI and the Defense Advanced Projects Administration (DARPA). During the past year the vapor lock problem that had been plaguing the rotor was solved. The rotor has been run several times and can now be filled with liquid helium. During its last run in May of 1991, the machine achieved nearly full speed operation at liquid helium temperatures. Two new problems with the rotor have been identified. Solutions for both have been designed and implemented, but not yet tested. The new radiation shield has been fabricated and appears to work as planned.

United States Navy

For several years now, under the direction of Professor Kirtley, the laboratory has provided educational opportunities to officers of the USN who attend MIT as graduate students. During this year we started a three-year research program, with sponsorship from the Office of Naval Research, into ways of simulating and assessing stability and control techniques for large, complex systems such as ship power supply and integrated electric drive systems.

In May of this year, Lt. Norbert Doerry finished a Ph.D. thesis in which he developed WAVESIM, a new and innovative framework useful not only for simulation but, we believe, for assessing system stability. WAVESIM provides an easy interface for lacing together the component elements of electromechanical systems and for implementing system studies. New and important concepts include the provision for mixed ways of representing waveforms (including several different orthogonal and non-orthogonal series representations), and the "system Jacobian" matrix, which provides information relative to problem decomposition. This work is being done under the direction of Professor Kirtley and Dr. Marija Ilic.

HIGH VOLTAGE AND INSULATION RESEARCH

Professor Zahn has continued his sensitive Kerr electro-optic field and space charge mapping measurements in weakly birefringent dielectrics that have applications to electric power apparatus and insulation systems. Transformer oil measurements complementary to the flow electrification measurements have shown increased levels of charge density and electric field at pressboard covered electrodes as the system moisture level and temperature are increased. The field and charge distributions also change when anti-static additive Benzotriazole (BTA) is added. Kerr electro-optic measurements are proceeding where the oil temperature, conductivity, and moisture level are continuously monitored over time. The results are being correlated with the flow electrification facility.

Graduate student Karen Walrath has been working on a project for Tokyo Electric Power Company developing a microwave method for detecting moisture and water trees in polyethylene power cables. The method uses evanescent waves from a dielectric waveguide in a way analogous to the use of infra-red light with attenuated total reflectance (ATM). The absorption is monitored as a function of microwave frequency to see how much absorption occurs at the absorption frequencies for water.

Professor Zahn is also a member of the Department of Energy Task Force on Electrical Breakdown of Insulating Ceramics in a High Radiation Field. He has been asked to prepare a proposal for Kerr electro-optic field and charge mapping measurements in electron beam irradiated sapphire, similar to prior work on electron beam irradiation of polymers. The purpose is to understand the high radiation induced conductivity of sapphire, which is used in fusion machines for high voltage insulation.

Professor Zahn is also a member of the Scientific Committee of the French Vacuum Society Interdisciplinary Conference on the Investigation of Dielectrics: Properties, Characterization, Applications, (March, 1992) where he will present a short course and two invited talks.

MANAGEMENT OF TECHNOLOGY

Although officially retired, Professor Lee continues to be active in the Sloan School's Management of Technology program. In addition to chairing the LEES Review Committee, he also chaired the National Academy of Engineering's study "National Interest in a Global Technology" and the Mitigation Panel of a National Academy of Science study on Policy Implications of Greenhouse Warming.

POWER ELECTRONICS

Professors Kassakian, George Verghese, and Martin Schlecht lead the laboratory's teaching and research activities in power electronics. They also continue to serve in leadership roles in the IEEE Power Electronics Society (PELS), Professor Kassakian as chair of the society's Nominating Committee and a member of the Governing Board of the European Power Electronics Society, Professor Verghese as a member of the PELS Administrative Committee, and Professor Schlecht as chairman of the 1991 IEEE Power Electronics Specialists Conference recently held at MIT. A major accomplishment this year was the publication of the textbook **Principles of Power Electronics** authored by Professors Kassakian, Schlecht and Verghese.

Professor Verghese and his students continue their research into the modeling and control of dynamic behavior in power converters. These efforts underlie his contributions to the book, a section of which is devoted to dynamics and control in power electronics. Much of this material has never been presented in book form before. The material is already providing the basis at some universities for new graduate courses devoted primarily to the dynamics and control of power converters.

Other recent accomplishments in this area include contributions to the April 1991 **IEEE Transactions on Power Electronics**, Special Issue on Modeling in Power Electronics. This issue contains four papers by Professors Verghese and Kirtley of LEES, Professor Jacob White (RLE), and various collaborators.

Work on advanced analog and digital control of high power-factor converters continues under support from, and in close collaboration with, the Digital Equipment Corporation (DEC). Hardware experiments are in progress, and have so far lived up very well to the expectations of earlier analytical and computational studies. A 1.5 kW, 300 V to 50 V front-end converter to be used in a distributed computer power supply system has been built. This converter, which includes power-factor correction, operates at a high frequency (1 MHz) to make its filter elements small so that the overall product will be more manufacturable.

A test facility for measuring and understanding electro-magnetic interference (EMI) from converters has been constructed. Techniques for measuring the effectiveness of an EMI filter and for determining the Thevenin equivalent circuit model of a power circuit have been developed. The practical application of active filter techniques to power supply EMI filters is being studied.

A highly paralleled architecture for power electronic converters has been the subject of new research by Professors Kassakian and Schlecht. Professor Kassakian presented an invited paper on this topic in Budapest in October, and Professor Schlecht has been working with DEC on applying the system concept to the design of highly efficient power supplies. New circuit techniques have resulted in a demonstrated efficiency of 90 percent compared to 82 percent for commercial products.

Professor Schlecht has proposed a new, low loss, approach to the design of logic circuits which integrates the power supply and logic element. An ac supply voltage is used instead of the traditional dc supply. This permits recovery of the energy stored in the parasitic capacitances of the integrated logic circuit. Simulations show a potential savings of 80 percent of the power normally dissipated in a CMOS circuit operating at 30 MHz. Work is proceeding on the development of special power supplies, logic circuit processes, and interconnection techniques required to fully demonstrate this efficient logic circuit concept at even higher frequencies.

In October, Professors Kassakian and Schlecht took four of their graduate students to the Technical University of Berlin (TUB) to participate in a workshop on power electronics organized by TUB, AEG, and MIT.

The MIT Summer Session course "Principles of Power Electronics" was once again offered by Professors Kassakian, Schlecht, and Verghese. This time the course was made available to university faculty interested in creating a curriculum in power electronics. Approximately 38 faculty and 14 engineers took the course.

POWER SYSTEM PLANNING AND OPERATION

Drs. Ilic and Richard Tabors lead the laboratory's teaching and research activities in the area of power systems planning and operation. Dr. Ilic has been particularly active in defining a longer term research agenda for the Laboratory in this area. She organized the second "MIT Workshop on Power Systems Monitoring and Control". Follow-up actions since the Workshop have included working closely with members of the staffs of the New England Power Pool (NEPOOL), the New York Power Pool (NYPP), as well as working visits to American Electric Power

(AEP) and Pacific Gas and Electric Co. (PG&E). All of these interactions have contributed to our thoughts on the research needs in this area, and have helped enormously in relating our theoretical efforts to the real needs in the operation of modern power systems. The resulting document entitled "Research Agenda for Power Systems Monitoring and Control: Voltage -Related Problems", by M. Ilic, LEES WP91-001 has been distributed to many U.S. utilities, electrical equipment and software manufacturers (Asea Brown Boveri (ABB), Power Technologies Inc. (PTI)), EPRI and also to some international utilities (Electricite De France (EDF), Tokyo Electric Power (TEPCO), Kansai Electric Power, Taipower and the Korean Electric Power (KEPCO)).

The New England utilities sponsored project on the development of smart algorithms for voltage monitoring and control is at the end of its second phase and the beginning of the third phase. The development of a production-grade version of this software is being strongly considered by the sponsors. The algorithm and software are also being used in the on-line environment. This should lead to a computer assisted scheduling mode which would help manage energy resources more efficiently than at present.

A new project sponsored by the New York utilities on large signal generator controls is in its first phase. The main theme of the project is to explore the potential of nonlinear control design on generators for improving the system's dynamic response.

A project sponsored by Electricite de France (EDF), scheduled to start September 1, 1991, is being awarded to investigate new solutions for automated control of the French national power system by coordinating already automated regional controls. It has been known for some time now that difficulties in coordinating regional controls have played a major role in the past blackouts on the French system. One of the leading EDF researchers is joining the MIT/LEES/LIDS team on this project.

Two new graduate subjects, Advanced Power Systems I and II, were initiated by Dr. Ilic in the Fall of 1990. The energy and communications networks within the national power system are as large and complex as any other man-made system. The educational program under development treats them as such, and as a result, the two new courses have attracted graduate students interested in applied systems, networks and control, as well as in computing techniques for very large scale systems.

Dr. Ilic has published the lead chapter in the Academic Press series on Advances in Control and Dynamic Systems, theme "Analysis and Control System Techniques for Electric Power Systems", vol.41, 1991. Both Dr. Ilic and Dr. Tabors remain active in national and international professional activities.

SYSTEMS IDENTIFICATION AND CONTROL

Parameter Estimation

Professor Verghese and his students, along with collaborators at the Technical University of Berlin, have demonstrated the feasibility of speed and parameter tracking in induction machines, using stator current and voltage measurements only. Their scheme exploits the structural features of induction machine models to decompose the estimation tasks into linear subproblems for which efficient real-time algorithms exist.

Professor Lang and his students have continued their development of observer-based controllers for electric machines. For a variety of electric machines, observers have been developed to accurately estimate machine motion from information obtained only at the electrical terminals. Thus, the need for the traditional motion sensors has been eliminated. On top of these observers, high-accuracy motion controllers have been developed, and these controllers have recently been made adaptive to external changes in the mechanical load.

Non-Intrusive Load Monitoring

The present trend in load management within the electric utility industry has focused significant attention on electric usage in commercial buildings. Professors Leslie Norford (Architecture), Kirtley, Verghese and Dr. Tabors are in the second year of a multi-year project funded by EPRI to develop and test means of monitoring electric loads in commercial buildings without the expense of individual load meters. The research team is developing both hardware and software based on work pioneered by the late Professor Fred Schweppe. Current results indicate that the method can identify and separate clearly the transients associated with the switching of motor and lighting loads. Further the methodology can differentiate between traditional iron-core and solid state lighting ballasts. During the past year the research has focused on monitoring and analysis of individual devices. The current year will see increased use of a physical building system within LEES and with the instrumentation of a large office building at MIT.

Regional Analysis of Electric Utility Environmental Impacts

Environmental residuals generated by the electric utility industry have become a major focus of legislation (the Amendments to the Clean Air Act) and public opinion (Global Warming). Under funding from the EPA, Dr. Tabors and students in the Technology and Policy program are modeling the impact of electric energy demand growth on the level of air emission in a region by region basis in the U.S. This is a pilot study which, if successful, will move to a nation-wide evaluation of utility emissions.

TRANSFORMER AND APPARATUS MONITORING

Research in the area of performance monitoring of large power transformers has continued and expanded into the monitoring of other apparatus. This research, having its origins in the project Trend Analysis - Performance Monitoring of Transformers, which ran from 1984 to 1988, has involved several projects specifically concerned with transformer monitoring, and a related one on the performance monitoring of motor-operated valves in nuclear power plants. LEES continues to support the development of a commercial transformer monitoring system at J.W. Harley, Inc. of Twinsburg, Ohio, and participate in collaborations with apparatus-monitoring researchers around the world - most notably, Professor I.J. Perez-Arriaga of the Instituto de Investigacion Technologica of Madrid.

Transformer Monitoring Using Vibration Analysis

This project, part of the Electric Utility Program (EUP), is co-supervised by Mr. Hagman and Professor Kirtley, and is aimed at the detection and diagnosis of structural damage in the windings of power transformers through the use of adaptive model-based monitoring. Work during the past year has focused on modeling of winding vibrations, the application of Taguchi experimental techniques to data screening, and the construction of a hydraulic ram to deform the winding of a test transformer while in operation. The project is one year old and has been sponsored from its inception by Boston Edison Company, Allegheny Power System, and Bonneville Power Administration. KEPCO joined the project as an additional sponsor in February of this year. An employee of KEPCO, Dr. No Hong Kwak, is now participating in the project as a visiting engineer.

A Non-Destructive Breakdown Measurement for Oil-Dielectric Strength Testing

This project, part of the EUP, is sponsored by the Empire State Electric Energy Research Corporation and is co-supervised by Dr. Cooke and Mr. Hagman. The research involves the development of an in-situ method for determining the dielectric strength of mineral-based oils in electric power apparatus. The approach used to achieve a non-destructive breakdown measurement consists of applying a fast rise-time, limited-duration, limited-energy, high-voltage pulse to an asymmetrical electrode pair, and measuring the time-to-breakdown of the electrode gap. Phase I of the project ended in January, 1991 with the viability of the method being demonstrated. Results achieved include the ability to detect moisture and particulate contamination in the oil while having the test remain insensitive to oil temperature and to oil flow (above a threshold flow rate).

Thermal Response Characteristics of the Hydran Dissolved-Gas-in-Oil Sensor

Typically, the Hydran sensor is used in the electric utility industry as an 'alarm' instrument, to detect dissolved-gas in power transformers at levels above 500 ppm. This recently-concluded project, part of the EUP, and co-supervised by Dr. Cooke and Mr. Hagman, was undertaken to achieve a better understanding of the thermal response characteristics of the Hydran Dissolved-Gas-in-Oil Sensor in the low parts-per-million (ppm) range. This research involved investigation of the Hydran sensor response when used as a monitor of dissolved-gas content in the range of 25 - 125 ppm. Results achieved included better understanding of sensor response through modeling of the overall operation of the sensor and its associated electronics package, and the development of a compensation algorithm for thermally-induced inaccuracies in the sensor reading at low ppm levels.

Electromechanical Monitoring of Motor-Operated Valves

This project is administered through the MIT International Program on Enhanced Nuclear Power Plant Safety and involves Mr. Hagman, Professor Lang, and Dr. Umans of LEES, as well as Professor Lyon of the MIT Machine Dynamics Laboratory. Motor-operated valves (MOV's) are a major source of failures in nuclear power plants. This project is applying adaptive-model-based monitoring concepts to operation of MOV's, with the intention of combining vibration monitoring with the use of the electric motor as a sensor to acquire the information necessary to determine the present condition of the valve, thereby supplying the human operator with information about how the valve will operate next time it is energized. Work during the past year has involved dynamic mechanical modeling of the power-transmission assembly and dynamic modeling of the electric motor to allow the determination of gear-train condition through the use of a combination of vibration monitoring (to determine gear-meshing frequencies and motor speed), and electrical monitoring of the motor (to determine instantaneous load torque).

Laboratory for Information and Decision Systems

The Laboratory for Information and Decision Systems (LIDS) is an interdepartmental research laboratory of the Massachusetts Institute of Technology. Its staff includes faculty members, full-time research scientists, postdoctoral fellows, graduate research assistants, and support personnel. Undergraduate students participate in the research program of the Laboratory through the Undergraduate Research Opportunities Program (UROP). Every year several research scientists from various parts of the world visit the Laboratory to participate in its research program.

The fundamental research goal of the Laboratory is to advance the field of systems, communication and control. In doing this, it explicitly recognizes the interdependence of these fields and the fundamental role that computers and computation play in this research. The Laboratory is conducting basic theoretical studies in communication and control, and is committed to advancing the state of knowledge of technologically important areas.

As an interdepartmental laboratory, LIDS reports to the Dean of the School of Engineering, Professor Joel Moses. The Co-Directors of the Laboratory are Robert G. Gallager, Fujitsu Professor of Electrical Engineering, and Sanjoy K. Mitter, Professor of Electrical Engineering.

The Center for Intelligent Control Systems (CICS), an inter-university, interdisciplinary research center operated by a consortium of Brown University, Harvard University and MIT, resides administratively within the Laboratory for Information and Decision Systems.

Twenty-eight faculty members, several research staff members and approximately 75 graduate students are presently associated with the Laboratory and the Center. Currently, the Laboratory and the Center provide some 50 research assistantships to graduate students. Undergraduate students also participate in research and thesis activities. A number of postdoctoral and visiting appointments are also made.

Financial support is provided by the National Science Foundation, NASA, the University Research Initiative Program (Army Research Office), Bell Communications Research, Inc., NYNEX, GTE, IBM, the C.S. Draper Laboratory, the Office of Naval Research, and the Air Force Office of Scientific Research.

NEW RESEARCH INITIATIVES

Coordination in Large Organizations

A new project funded by NSF and involving collaboration with researchers from the University of Connecticut started this year under the direction of Professor Michael Athans. The goal of this project is to develop normative/descriptive models of small and large organizations in which the decision-makers do not have identical information. The paradigm of distributed hypothesis testing is used to assess the performance of different organizational architectures, for both optimal and suboptimal decision rules, and the development of adaptive training algorithms for the organization as a whole.

Dynamic Control of Large Space Systems

A new set of projects involving issues of robust and decentralized control for large space structures was initiated this year by Professor Athans and several students. The research involves significant interactions with faculty and staff from the MIT Space Engineering Research Center and staff from the C.S. Draper Laboratory, Inc. In addition to theoretical research, designs of multivariable control systems for a space-based interferometer testbed and a computer model of a space-based laser are being carried out.

Identification and Adaptive Control

Determining the fundamental limitations and capabilities of identification and adaptive control has become an active area of research carried out by Professors Munther Dahleh, John Tsitsiklis and Sanjoy Mitter and their students. This newly initiated research program draws upon areas such as information-based complexity theory and computational learning theory as well as upon the theory of robust control.

Machine Learning

In recent years there has been a great deal of interest in the theoretical foundations of machine learning. One goal of this work is to identify the limits of what is and is not possible, such as information theory does for communications or the theory of computation does for computing. One particular framework that has received much attention is a distribution-free model often referred to as the Probably Approximately Correct learning model. The focus of research in LIDS is on analyzing such learning frameworks with a view towards extending their domain of applicability into areas such as machine vision and system identification. Professors Sanjoy Mitter and John Tsitsiklis and their students are involved in this work.

CURRENT RESEARCH

Multi-Resolution Statistical Signal Processing

For some time now there has been considerable interest in algorithms for the processing of signals or images that examine data at multiple resolutions. In the recent past, a theory involving the so-called "wavelet transform" has been developed for the deterministic representation of signals at multiple resolutions, and this has sparked a considerable response from the research community in exploring potential applications in a variety of areas ranging from computer vision to the fusion of multispectral measurements. An essential element in the development of a systematic methodology for the design of multiscale algorithms is the development of a statistical theory for multi-resolution signals. Efforts to develop such a theory are underway by Professor Alan Willsky at LIDS together with a group of researchers in Rennes, France. The initial results that have been obtained, together with the considerable attention this topic is receiving from the research community lead us to believe that this will be an extremely fruitful area for some years to come.

Three-Dimensional Structure Determination

Problems of three-dimensional chemical structure determination provide several test-bed problems for three-dimensional random field estimation which are simultaneously of great intrinsic importance. Solution of these problems is crucial to the understanding of natural biological molecules and for the engineering of novel new modified molecules--catalysts for industrial processes, drugs, and so forth. Furthermore, this is currently a field of intense interest in chemistry and biology with many eager collaborators within MIT. Finally, the understanding developed by studying these three-dimensional problems will transfer to other three-dimensional problems such as signal processing for sequences of images and atmospheric/oceanographic/seismic sensing with detailed, and therefore, three-dimensional, models. To address these problems, a research program involving Professor Sanjoy Mitter and Professor Alan Willsky is ongoing.

Data Communication Networks

Research in Communication Science and Systems ranges from basic information theoretical studies of networks and communication channels to the architectural design of network protocols. The major objective of this work is to develop the scientific base needed to design data communication networks that are efficient, robust, and architecturally clean. Both wide area and local area networks, both high speed and low speed networks, and both point-to-point and broadcast communication channels are of concern. Some of the topics in this area are multiaccess communication processes, routing, congestion control, diverse traffic mixes, the communication complexity and delay of distributed algorithms, failure recovery, and topological design. Professors Dimitri Bertsekas, Robert Gallager, and Pierre Humblet are conducting this research.

Fiber Optic Communication Networks

The goal of this work is to identify and resolve the new fundamental network design issues that arise when very broadband optical fiber technology is used. It differs from past network research in that the emphasis is upon effective utilization of the enormous excess bandwidth that this technology makes available rather than upon minimizing the bandwidth the network requires. In the bandwidth-rich situations addressed by this work, the usefulness of such traditional bandwidth conserving techniques as switching and packetization must be re-examined. Professors Pierre Humblet and Robert Kennedy are conducting this research which includes theoretical and experimental components.

This research is related to a bigger effort on optical networks which is led by Prof. Kennedy and Vincent Chan from Lincoln Laboratory. Faculty from other parts of the department and also Lincoln Laboratory are involved. It may lead to the creation of a consortium funded by DARPA that would include AT&T, DEC and IBM, as well as M.I.T.

Estimation, Statistical Signal Processing, and Inverse Problems

A variety of stochastic estimation, analysis and signal processing problems are being studied by Professors Sanjoy Mitter, George Verghese, and Alan Willsky and their students. Theoretical studies are conducted in the areas of estimation algorithms for spatially distributed random processes, nonlinear filtering, relationships among filtering problems in scattering theory, and the analysis of large-scale systems subject to a variety of very rare events. Complementing this theoretical research are more applied projects, including the design of algorithms for detecting and compensating for sensor or actuator failures, and the development of model-based signal processing algorithms. The specific signal processing problems include the diagnosis of arrhythmias in electrocardiograms, the detection of objects or anomalies given tomographic measurements such as those made using X-rays or ultrasound in medical and industrial nondestructive testing applications or in laser radar imaging systems, the analysis and inversion of spatially-distributed geophysical data, image processing and understanding, and computational vision.

Discrete-Event Dynamic Systems

During the past few years there has been considerable interest in the development of control concepts and algorithms for complex processes that are characterized more by the occurrence of discrete events than by differential equations representing the laws of physics. Such processes are typically man-made--flexible manufacturing systems, computer networks, etc.--and

are often best described in symbolic, rather than numeric form. Professor Willsky's research is aimed at combining concepts from computer science and from control in order to develop a meaningful theory of control of such systems. In particular, the models and formalisms used in such a study come from the field of computer science (automata, synchronous processes, etc.), while the problems and design paradigms come from control (stability, regulation, robustness,...). The results to be obtained from this study should be of value in such diverse applications as distributed database management and flexible manufacturing.

Multivariable and Adaptive Control

Systematic design of multiple-input-multiple-output systems, using a unified time-domain and frequency-domain framework is an extremely active research area in the Laboratory. Various theoretical and applied studies are being carried out by Professors Michael Athans, Munther Dahleh, Sanjoy Mitter, Gunter Stein and Lena Valavani and their students. Theoretical research deals with issues of robustness, aggregation, and adaptive control. Recent application-oriented studies include the control of large space structures, helicopters, submarine control systems, engine control system designs, and issues of integrated flight control.

Deterministic and Stochastic Nonlinear Dynamical Systems

The theory of nonlinear systems, both deterministic and stochastic, has developed rapidly during the last ten years. There is increasing interest in deterministic nonlinear control and various problems of adaptive control which lead to problems of nonlinear control. In the context of stochastic dynamical systems, problems of the qualitative behavior of such systems under different time-scales are of great interest. Recent work on nonlinear filtering has shown a relationship to infinite-dimensional, bilinear systems, and there is increasing interest in the understanding of qualitative behavior of nonlinear filters for large and small time-intervals. Finally, research is under way on the subject of control of discrete-event systems. Various investigations in this area are being conducted by Professors Michael Athans, Sanjoy Mitter, John Tsitsiklis, George Verghese, Alan Willsky and their students.

Theory and Algorithms for Optimization

This project focuses on analytical and computational methods for solving broad classes of optimization problems arising in engineering and operations research, as well as for applications in communication networks, control theory, power systems, computer-aided manufacturing and other areas. Currently, in addition to traditional subjects in nonlinear and dynamic programming, there is an emphasis on solution of large-scale problems involving network flows as well as in the application of decomposition methods. The thrust is twofold: first, to find ways to handle the typically huge number of constraints; second, to explore the use of distributed and parallel processing to reduce the computation time needed to solve a problem and to economize on information transfer from remote data collection points to a computation center. This gives rise to fundamental issues involving the synchronization of computation and communication that are as of yet only partially resolved. Professors Dimitri Bertsekas and John Tsitsiklis and their students perform this work.

The Nematode as a Model Complex System

Dr. Charles Rockland and Professor Sanjoy Mitter, joined by Mr. Steve Rowley, have continued work on this project. This work has included setting up some of the general software framework, "structures" and "models," which in particular associate dynamics to the structures. An initial implementation of this framework, carried out on Symbolics Lisp machines, has been applied to some motor nervous system models.

Information Transfer and Retrieval

Research on information transfer retrieval focuses on making interaction with computer based information systems easier and more effective for human users. This research is supervised by Mr. Richard S. Marcus. A current project involves the development and testing of an expert computer retrieval assistant that should help make searching a quantified science rather than an informal art through proper structuring of, and operations on, verbal descriptions of database objects. These objectives are to be obtained through such (semi) automated techniques as (1) derivation of a conceptual formulation of a user's problem and its translation into an initial search strategy; (2) ranking by estimated relevance of documents retrieved thereby; and (3) analysis of user relevance feedback to (a) estimate the number of relevant documents not yet retrieved and (b) reformulate the search strategy to retrieve those missing nuggets. Experiments with a precursor to the expert system have already demonstrated retrieval effectiveness, in terms of numbers of relevant documents found, equivalent to that achievable by human information specialist acting as a search assistant. Partly based on this research, a series of operational and retrieval assistant systems have been developed.

System, Reliability and Risk Management

Research on risk assessment and management is carried out in many MIT departments and laboratories. At LIDS there is interest in describing the reliability of complex systems in terms of what is known about the reliability of their components. Professor Alvin Drake has supervised research on the development of models and algorithms for studying the manner in which uncertainties about component reliabilities are reflected in uncertainty about system reliability. The primary area of application has been to low probability, high consequence risks in nuclear reactor safety. Professor Drake

is also concerned with probability assessment, particularly the quantification of expert judgment. A current project is detailed probabilistic analysis of the sequence of tests used to screen donated blood for the presence of AIDS-associated antibodies.

Center for Intelligent Control Systems

The Center for Intelligent Control Systems (CICS) combines distinguished faculty from MIT, Harvard University and Brown University in interdisciplinary research on the foundations of intelligent machines and intelligent control systems. Established in October 1986, CICS is headed by Professor Sanjoy Mitter, Director; Professor Roger Brockett, Harvard University, Associate Director; and Professor Donald McClure, Brown University, Associate Director. The research activities of the Center are loosely grouped into five areas: Signal Processing, Image Analysis and Vision; Automatic Control; Mathematical Foundations of Machine Intelligence; Distributed Information and Control Systems; and, Algorithms and Architectures. A number of outstanding graduate students are appointed Graduate Fellows. The Center also hosts several senior visitors for varying lengths of time each year.

Speakers in the 1990/91 CICS Colloquium Series included: Frederick Jelinek, IBM T.J. Watson Research Center and Michael Shub, IBM T.J. Watson Research Center. Two workshops were organized by CICS Faculty: the Workshop on VLSI and Computer Vision and the Workshop on Analog, Neural and Asynchronous Computing, April 1991.

VISITORS TO THE LABORATORY

Among the visitors this year were: Dr. G. David Forney, Vice-President, Codex Corporation based at Motorola, Dr. Hans Witsenhausen, Dr. Ofer Zeitouni, Technion, Dr. Michael Caramanis, Boston University, Dr. Bosheng Hu, Xian Jiaotong University and Dr. Joseph Bokor, Hungarian Institute of Technology among others.

HIGHLIGHTS

Fifty Years & Beyond - A Symposium in Celebration of the 50th Anniversary of the Laboratory for Information and Decision Systems. In this symposium present and former faculty associated with the Laboratory highlighted ongoing research and future activities in Communication (including Broad Band Communication Networks), Control (including Intelligent Control), Signal Analysis and Parallel and Distributed Systems. There were also lectures by leading figures from industry on Automation and Communication. The symposium closed with a panel discussion to assess the future of the field of Systems, Control and Communication with participation by distinguished members of academia, industry and government. The symposium was opened with a reception at the M.I.T. Museum where a collection of photographs, narratives, artifacts, and motion picture films portraying activities of the Laboratory over the past fifty years were exhibited. Also on display were some fifty books authored by present and former Laboratory staff members and students. A banquet was held in honor of the event in which Dr. Aaron Cohen, Director, Johnson Space Flight Center, gave an address entitled "The Next Fifty Years of Space Exploration."

Professor Roger Brockett, Associate Director of CICS and An Wang Professor of Engineering and Computer Science at Harvard University, has been elected to the National Academy of Engineering, 1991.

Professor Dahleh received a 1991 Young Presidential Investigator Award from NSF and was promoted from Assistant Professor to Associate Professor of Electrical Engineering and Computer Science.

Professor Pierre Humblet was granted this year's NEC Award and was promoted from Associate Professor to Professor of Electrical Engineering and Computer Science.

Dr. Y.Z. Tsytkin, Academy of Sciences, U.S.S.R. visited the Laboratory to give a Colloquium entitled "Control of Systems with Uncertainty: Past, Present and Future."

Professor George Verghese is co-author with Professors Kasakian and Schlecht, of a recently published textbook, "Principles of Power Electronics," Addison-Wesley, 1991. This is the first book in its area to devote substantial attention to issues of dynamics and control. One of the four parts of the book is dedicated to this aspect of power electronic systems.

Professor Alan Willsky was the Plenary lecturer at the SIAM Annual Meeting, Chicago, July 1990, the Spring 1991 Distinguished lecturer at the Signal and Image Processing Institute, USC, in February 1991, and keynote speaker at both the MIT/EECS Department Colloquium, April 1991 and the IEEE International Conference on Systems Engineering, Dayton, Ohio, August 1991. In addition, work with Jerry Prince on Geometric Reconstruction has appeared as an invited paper in the SPIE Journal on Optical Engineering and work with Cuneyt Özveren on Discrete Event Dynamic Systems has been the subject of invited presentations at the June 1991 IFAC Symposium on Intelligent Control Systems.

Laboratory for Manufacturing and Productivity

The Laboratory for Manufacturing and Productivity (LMP), an interdepartmental laboratory in the School of Engineering, was established in 1977 to conduct engineering research and develop the fundamentals of manufacturing science. Currently, 20 faculty members, 4 research staff, 60 graduate students, and 30 undergraduates conduct manufacturing research jointly with industrial and government partners. The primary research focus is on the engineering fundamentals of manufacturing, with an emphasis on processes. Rather than developing better methods of coping with complex manufacturing systems, the LMP's goal is to reduce the systems' inherent complexity through improved understanding of processes and systems. This approach enables us to blend basic research involving real-world industrial problems.

In addition to our research agenda, the faculty associated with the LMP are attempting to create a manufacturing discipline by continuously refining the curriculum used to educate engineers in the field of manufacturing, and several are playing a major role in the Leaders for Manufacturing Program. Curriculum development is extremely important, because there are very few formal mechanisms in the U.S. for educating students in the area of manufacturing. While "on-the-job" training has sufficed in the past, the increasing complexity of today's manufacturing environment requires an advanced understanding of physical processes, as well as interdisciplinary proficiency.

As an interdepartmental Laboratory, the LMP reports to the Dean of the School of Engineering, Professor Joel Moses. David Hardt, Leaders for Manufacturing Professor of Mechanical Engineering, serves as Director, Dr. Andre Sharon serves as Associate Director, and Ms. Sally Stiffler serves as Assistant Director for Administration.

Since it is virtually impossible to address issues in manufacturing without considering the needs of industry, it is crucial that close ties between the Laboratory and manufacturing companies be maintained. In fact, over 50 percent of the research conducted in the LMP is sponsored by industry. Many of the sponsoring companies participate in our industry consortia, which include the Composite and Polymer Processing Program, the Tribology Program, the Microcellular Plastics Program, and the 3-D Printing Consortium. Further technology transfer is facilitated by the LMP Industrial Collegium, presently comprising over 35 companies with a common interest in manufacturing. The collegium serves as an information channel between industry and the LMP, and is administered by Mr. John Keene who serves as Coordinator of the Collegium.

RESEARCH AREAS

Research activities in the LMP encompass the following areas:

- Process Innovation
- Design/Manufacturing Integration
- Tribology
- Scheduling and Production Planning
- Flexible Automation

Process Innovation

A large portion of our research is aimed at alternative manufacturing processes that are inherently less complex, and hence more predictable and consistent. Consistency can be further increased through real-time process control. The evolution of the process is continuously monitored and the input parameters are adjusted to eliminate errors caused by unforeseen parameter variations and process disturbances.

Current projects in this area include novel methods of fabricating composites, real-time control of metal forming and welding processes, polymer processing, spray forming of metal-matrix composites, microcellular plastics, laser machining, and three dimensional printing.

Tribology

Tribology provides a better understanding of wear mechanisms, which in turn leads to a more predictable and reliable product. Ongoing projects at the Laboratory are exploring wear mechanisms in various applications, including magnetic recording media, electrical contacts, and piston-cylinder interaction in internal combustion engines.

Flexible Automation

Flexible automation facilitates small-batch manufacturing, which will very likely be the standard mode of operation in the future. It is our goal to extend the capabilities of flexible automation through novel hardware, software, and control strategies.

Current research is focused on mid-volume automation, rapid prototyping, reconfigurable fixtures, reconfigurable die-surfaces for metal and composites forming, and versatile control strategies.

Design/Manufacturing Integration

This emerging area concerns itself with the integration of the various phases associated with turning a concept into a deliverable product. These phases include design, manufacturing, quality control, marketing, etc. Much research is needed to develop the formal methodologies and tools that will facilitate such integration. Current efforts in the Lab are focused on formalizing the design process, as well as providing tools such as expert systems to aid the designer.

Scheduling and Production Planning

Managing and optimizing product flow through a factory is crucial to manufacturing competitiveness. In the LMP we are conducting research aimed at modelling and "optimally" scheduling the flow of product through manufacturing lines.

THE 1991 LMP-INDUSTRY COLLEGIUM MEETING

The 1991 biennial meeting of the LMP-Industry Collegium was held this past April. This year's theme was Rapid Response Manufacturing. Researchers from the LMP presented their latest visions and research results relating to the above theme. The two-day meeting was well-attended by over 100 industrial managers, engineers, and academics from over 55 national and international corporations and universities.

NEW APPOINTMENTS

Dr. Alexander Slocum will be joining the LMP in September, 1991 as Assistant Professor of Mechanical Engineering. Professor Slocum conducts research in precision engineering and machine design. His research has led to the development of ingenious designs, such as a self-coupling hydrostatic leadscrew, an atomic resolution measuring machine, and an accelerometer calibration machine.

Professor Slocum, a former member of the MIT faculty in the Department of Civil Engineering, spent five years on the MIT faculty and one year at the Cranfield Institute of Technology. He received his B.S., S.M., and Ph.D. in mechanical engineering from MIT and was named Presidential Young Investigator in 1988. He holds 9 patents and has written a text book, *Precision Machine Design*, which promises to become the standard textbook for teaching precision (and nano) machine design.

NEW INITIATIVES

Manufacturing Institute

Professor Nam Suh and Dr. Andre Sharon of the LMP, along with other faculty, are in the process of forming a "manufacturing institute" at MIT. The Manufacturing Institute will serve as a research, development, and implementation (RD&I) organization that will take a research concept from its evolution to its implementation on the factory floor. Prominent researchers and engineers from MIT, other academic institutions, and participating industrial firms will work, in partnership, on major cross-disciplinary projects that will significantly impact US manufacturing capabilities. The Manufacturing Institute will also serve as a structural model for effective use and development of academic research into working technologies for US industry.

3-D Printing Consortium

Professor Emanuel Sachs has founded the 3-D Printing Consortium, currently comprising six industrial firms which work in partnership with MIT researchers. Three Dimensional Printing is a process under development at MIT for the rapid and flexible production of prototype parts and tooling directly from CAD models. By allowing for the rapid production of prototype parts, 3-D Printing can substantially reduce the time to market for new products.

Three Dimensional Printing functions by building parts in layers. Each layer is created by spreading a thin layer of powder and then selectively joining the powder within the layer by depositing a binder using a process similar to ink-jet printing. The process is repeated until the complete part is built. The loose powder is then removed, revealing the complete part.

NOTE

We are once again bidding a partial farewell to Professor Nam Suh, who has recently been appointed Head of Mechanical Engineering at MIT.

DAVID E. HARDT
ANDRE SHARON

Leaders for Manufacturing Program

The Leaders for Manufacturing (LFM) Program serves as an Institute response to numerous questions posed by US manufacturers about productivity improvement for greater global competitiveness. The program is addressing issues for improving American industrial performance that the MIT Commission on Industrial Productivity raised during its two-year study of eight US manufacturing industries. Launched in the spring of 1988 under the (continuing) co-directorship of H. Kent Bowen, Ford Professor of Engineering in the School of Engineering, and Thomas L. Magnanti, George Eastman Professor of Management Science, the Leaders Program draws on more than seven years of research and discussion among industry leaders and MIT faculty.

The Leaders Program began as a five-year experimental educational/research collaboration between 11 major US manufacturing firms and MIT's Schools of Engineering and Management. Its overall goals are to discover, codify, and apply guiding principles for manufacturing; educate future manufacturing leaders; and develop a new cadre of manufacturing faculty. The program adopts a "total enterprise approach" to manufacturing: in bridging the traditional technology and management "cultural divide," it integrates all key functions and disciplines involved in creating, designing, making, and selling/servicing products. This "big-M manufacturing" approach includes not only the corporation, but also its customers, vendors, and suppliers, its community, and the government.

The essence of the program can be summarized as partnership, people, and principles. The *partnership* is tripartite, consisting of industry and MIT's Schools of Engineering and Management; its *people* include company leaders and practitioners, faculty, and students. The *principles* include those now guiding current best manufacturing practice and those that emerge as new paradigms.

This report offers a few program highlights during the past fiscal year, then summarizes progress in each "product area" specified by the LFM Operating Committee as being essential to achieve broad program goals.

LFM HIGHLIGHTS, 1990-91

- *Academic environment changes: manufacturing curricula and faculty development*
 - Program faculty introduced three new courses this past year: 3.555/15.783 Product Design and Manufacturing, 15.766 Total Quality Management, and 15.792J Proseminar in Manufacturing (revised).
 - Program faculty have significantly modified two courses: 2.810 Fundamentals of Manufacturing Processes, and 15.761 Operations Management.
 - Five untenured faculty have been promoted — two receiving tenure — while conducting nontraditional interdisciplinary, manufacturing-related research with the support of the Leaders Program.
- *Industry environment changes: manufacturing research impact and careers*
 - One fellow in the Class of 1991 discovered that his host company could save tens of millions of dollars annually in inventory carrying costs, revenue opportunity cost, and variable capital costs by focusing more on flow time rather than head count reduction when coming down the learning curve. Another fellow in the same class developed a plan for a flexible, responsive system that could save his host company about \$1.5 million in inventory costs each year.
 - One fellow in the Class of 1991 accepted a position in a partner company with the potential for promotion to production area manager within six months. A second graduate in the same class is now heading up several product development teams in a manufacturing company.
 - One member of the LFM Fellows Class of 1990 has been promoted to plant manager.
- *Conferences*
 - The program held its first major symposium to share "the LFM Way" with leaders from industry and academia. More than 400 individuals attended, representing more than 80 firms, almost 60 universities, and about 10 government organizations.
 - The Leaders Program hosted a two-day conference on manufacturing curricula, funded by the Alfred P. Sloan Foundation, which attracted more than 110 attendees, including leading educators and practitioners in manufacturing, representing over 50 business and engineering schools.
 - The Leaders Program assisted with the 1991 Operations Management Workshop, bringing together faculty from many of the leading business schools and several leading practitioners from industry.
- *Accommodations for program growth*
 - The Leaders Program moved from Building 9 to larger quarters in Building E40, where several rooms are dedicated to student use on team projects.
- *Grants*
 - The Alfred P. Sloan Foundation awarded the Leaders Program \$400,000 to develop a manufacturing core content.
 - The program awarded the first Robert N. Noyce Fellowship, through a grant made this past year to LFM by the Intel Foundation.

GRADUATE TRAINING, PLACEMENT, AND SUPPORT

Curricula

By experimenting and taking risks, the Leaders Program seeks to build identifiable, comprehensive manufacturing curricula that differ significantly from current models. The program draws on MIT's strengths in engineering and management to teach Leaders students the fundamentals of both technology and manufacturing management.

A key educational component is the Fellows Program: a two-year graduate experience integrating management and engineering, including a six-and-a-half-month internship at a sponsor company's plant site. Students in this segment of the program receive fellowships to gain valuable experience working on major issues of interest to MIT and participating companies while earning two master's degrees, in management and engineering. The curriculum emphasizes teamwork, change management, learning by doing, and the integration of technology and management; it provides students with substantial opportunity to learn and experience leadership. In addition, it aims to instill within students an appreciation for continuous incremental improvement as well as groundbreaking, innovative improvement — and the total manufacturing enterprise's responsibility in producing both. Three themes comprise the LFM "educational pyramid": *leadership*, at the top, embraces all other activities and gives them focus; *integration* brings together the various supporting disciplinary building blocks — the *foundations* of knowledge, technical and nontechnical.

The fellows' curriculum is dynamic, changing as program participants learn. This past June, company representatives joined LFM faculty for several days to consider the existing curriculum and plan its continuing evolution. During two of the days, the Leaders Program hosted a conference funded by the Alfred P. Sloan Foundation focusing on manufacturing curricula (programs, courses, and activities), attracting more than 110 attendees, including leaders in the US academic and business communities; all major universities with manufacturing programs attended. Earlier in the year, the Sloan Foundation awarded the Leaders Program \$400,000 to develop a manufacturing core content in the form of new course modules codifying basic manufacturing principles critical to teaching future manufacturing leaders.

Faculty have developed six new courses as a result of participation in the Leaders Program. This past year, the faculty introduced 3.555/15.783 Product Design and Manufacturing and 15.766 Total Quality Management; the program also completely revised 15.792J Proseminar in Manufacturing to focus on leadership. Currently under development is an undergraduate elective course, 6.040 Engineering Statistics, which is expected to be introduced this fall.

The LFM Program is enhancing existing courses with the broader perspective offered by manufacturing education and research. Issues gleaned from Leaders projects and classes have impacted such courses as 2.810 Fundamentals of Manufacturing Processes, and 15.761 Operations Management. In addition to altering Institute course offerings in engineering and management, the Leaders Program's experiential learning and teamwork emphases are fundamentally influencing faculty teaching styles.

Graduates

The Leaders Program seeks to attract some of the nation's most capable, farseeing young people to the challenging, multidisciplinary field of manufacturing, to educate and return them to the workforce with value added. Since its inception in 1988, the program has funded the education of approximately 180 graduate students. This past year, 227 received LFM Fellows Program applications, compared to 191 applicants during the prior year. The Class of 1993 comprises forty-one fellows, including nine women and three underrepresented minorities; 13 fellows are sponsored by LFM partner companies. One new fellow has been awarded the program's first Robert N. Noyce Fellowship, made possible by a grant this past year to the program from the Intel Foundation.

The second class of 32 Leaders fellows graduated this past spring, joining the program's first class in the LFM alumni association, which assists the program through representation on its Governing Board and Operating Committee, student recruiting, and other supportive activities. The third class of 35 Leaders Fellows is at work on their internship projects; a fourth class (41 Fellows) has begun its coursework.

Since the program's inception, LFM has also fully or partially supported 70 research assistants earning master's degrees or doctorates through manufacturing-related research (*see the Longer-term basic research and Unrestricted junior faculty research sections of this report*).

Careers

The Leaders Program aims to develop attractive career paths in manufacturing that are intellectually challenging and financially competitive, and that provide opportunities to lead and effect change. Of the second graduating class, approximately 69% accepted positions within manufacturing companies (18 in partner firms), roughly equivalent to the proportion in the first graduating class. The remainder of the class have assumed positions with other types of companies, including consulting firms (primarily in manufacturing practices). The Leaders Program expects that all of the graduating fellows will ultimately assume positions in manufacturing companies.

The program continues to work with the partner companies to improve their recruiting strategies, methods, and career opportunities in manufacturing, bringing these more in line with what the fellows have cited as being most important in their career aspirations: potential for making a difference, especially regarding growth, impact, and starting responsibilities. This year's graduates' starting job assignments reflect high expectations for their abilities to understand and employ technology, to manufacture, and to lead. One fellow, for example, accepted a position in a partner company with the potential for promotion to production area manager within six months; a second is heading up several product development teams in another manufacturing company. One member of the LFM Fellows Class of 1990 is now a plant manager, within a year of graduating from the Leaders Program.

COLLABORATIVE PROCESSES AND MODES OF OPERATION

Collaboration

The Leaders Program aims to create structures and incentives for meaningful collaboration among participants to determine program content, processes, and products. Five departments in MIT's School of Engineering — Aeronautics & Astronautics, Chemical Engineering, Electrical Engineering & Computer Science, Materials Science & Engineering, and Mechanical Engineering — are cooperating with the School of Management and 11 firms. More than a hundred industrial practitioners currently work in the program with 52 MIT faculty, 76 fellows, and approximately 37 graduate research assistants. The LFM Program has brought industry expertise to the classroom in the form of seminar leaders, laboratory section teachers, and lecturers; industry people also assist with curriculum design.

Eighteen senior faculty, awarded Leaders for Manufacturing professorships, serve as liaisons to the partner firms. In the past three years, faculty have logged more than 200 visits to company sites, learning about some of the most pressing issues the firms face and bringing fresh ideas to resolve them. The companies, in turn, have provided experienced people to help manage the program and co-supervise the students' internship projects.

Manufacturing Faculty

The Leaders Program is well along in the process of building a faculty whose members not only exhibit strong disciplinary skills, but also willingly collaborate in discovering and verifying new manufacturing principles. Fifty-two Institute faculty are affiliated with the Leaders Program. Five untenured faculty have been promoted — two receiving tenure — while conducting nontraditional interdisciplinary, manufacturing-related research under the support of the Leaders Program. Three new faculty in the MIT Sloan School of Management have solid backgrounds in technology. The Leaders Program benefits from additional expertise provided by Donald Ephlin (former international vice president of the UAW) and Donald Davis (former chief executive officer of Stanley Works), both of whom serve in the capacity of senior lecturer.

Continuous Improvement

The LFM Operating Committee has specified that continuous improvement characterize all Leaders activities. In this spirit, during the past year the program hired Marcia Chapman as operations manager to coordinate staff activities, oversee the program budget, handle equipment and physical space requirements, and coordinate planning and follow-up activities of the program's governing board and operating committee.

Primarily to accommodate the dramatic and continuing increase in fellows, the Leaders Program moved in March to the fourth floor of Building E40. Students now have, in addition to sufficient carrel and computer space, several rooms dedicated to their use for collaborative work on team projects, increasingly seen as vital in a discipline that requires teamwork in actual practice. In addition, more suitable space is available for company visitors, which is intended to encourage more frequent company visits to campus, and thus closer collaboration. Renovations currently underway on the second floor of Building E40 will make this space available for program use, as well.

In addition, a Kodak employee proficient in organizational management, James Moore, has continued to advise the program on improving its management, including Governing Board and Operating Committee functioning, and streamlining staff functions.

PARADIGM SHIFTS AND TECHNOLOGICAL DEVELOPMENT

Interdisciplinary Research

The Leaders Program is attracting some of the best possible discipline-based faculty and company experts to conduct manufacturing-related research that will prove or disprove existing paradigms (i.e., principles) that are currently believed to govern manufacturing practice, and suggest new paradigms for further research and possible inclusion in manufacturing-related curricula. The program encourages interdisciplinary research teams and activities, with company collaboration (e.g., by using factories as real-life laboratories and as subjects for cross-company comparative studies).

The LFM research component is a multidimensional effort linking university research capabilities to relevant problems grounded in industrial needs — an effort vastly aided by the partner companies' substantial human and capital resources. The Leaders Program funds three types of research: fellows' projects at partner companies, longer-term basic research, and

unrestricted junior faculty research. Together, these research opportunities involve approximately 50 Institute faculty members.

Fellows' projects

The fellows' projects, each conducted primarily during six and a half months of work at an industrial site, offer program participants a broad exposure to manufacturing needs; the program has completed more than 50 projects. Student teams, supervised by faculty and industry associates, address issues identified by LFM faculty/partner firm collaborators to be of special concern to both the sponsoring companies and the broader manufacturing community. The partner companies' different markets, technologies, and cultures afford ideal test beds for program participants to learn the underlying principles of future manufacturing.

The companies continue to leverage their involvement in the program to conduct research collaboratively with other companies: this past year, Digital Equipment and Boeing conducted a joint project involving two fellows, to help introduce a new manufacturing system employing DEC hardware and software at Boeing. A two-year set of five internships at Hewlett-Packard linked strategic investment with process characteristics. Four internships at Chrysler linked aspects of a single platform development project.

Among the more intellectually notable internship projects this past year, one fellow gained an overview of a set of interdependent manufacturing processes to determine where improvement would be most effective. Another student offered a comparative analysis of organizational and technical strategies in the processing, design, casting, construction, and tryout of hard die tooling for body panels. A third developed an economic model for establishing process specifications in submicron gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) manufacturing. And a fourth fellow developed a systematic method for evaluating and selecting rapid prototyping processes.

The fellows' internship projects are tangibly impacting the partner companies. This past year, one fellow discovered that his host company could save tens of millions of dollars annually in inventory carrying costs, revenue opportunity cost, and variable capital costs by focusing more on flow time rather than head count reduction when coming down the learning curve. Another fellow developed a plan for a flexible, responsive system that could save his host company about \$1.5 million in inventory costs each year.

Longer-term basic research

The fellows' research projects serve as a backdrop for longer-term intellectual efforts in manufacturing. Most of this basic research is conducted at MIT, preferably through collaboration among Leaders faculty that cuts across traditional disciplines. The faculty have elected to favor projects that differ in content and style from traditional academic research, and that encourage students and faculty to work together in teams. The program is facilitating the development of long-term working relationships between university and industry people, believing that ongoing thought and effort are required to transform the myriad pieces of experience available in industry into a set of logical principles. These principles would establish manufacturing as a solid intellectual discipline in its own right, making possible the teaching of world-class manufacturing. Program participants have rejected the traditional short-term research project mode of tackling specific problems as a viable method for accomplishing such a task, and have instead matched faculty "research liaisons" with company people for long-term collaboration. Currently, the program funds 23 long-term research projects. One is developing spatial yield models for wafer fabrication to use in developing screening policies. Another investigates the management of concurrent engineering processes. A third involves designing and implementing a computer-aided design (CAD) system utilizing high-speed graphics and active input devices, to determine its effects on the design process. A fourth is a collaborative effort on process planning in metal-forming operations.

Unrestricted junior faculty research

The Leaders Program also awarded 15 grants for unrestricted research to its junior faculty this past year, supporting the study of a broad range of topics. One project is investigating innovative organizational forms to support problem-solving in the introduction of new process technologies. Another involves modeling of iteration in design procedures to reduce development time. A third project aims to develop optimization models for planning and scheduling printed circuit board assembly operations.

Implementation and Leadership

The Leaders Program seeks to facilitate and reward people interchanges to further the dissemination and implementation of the program's knowledge base. It seeks to develop a process and network for assuming leadership in conceiving and effecting positive changes in this country's manufacturing industry, and for rapidly exchanging concepts, ideas, and results among all its stakeholders (i.e., its partner firms and other US firms; MIT faculty, students, and administration; other universities; and the US government) — especially to help its partner companies assimilate the program's products and change their manufacturing practices accordingly.

The Leaders Program held its first major symposium, *New Partnerships for Manufacturing Excellence*, in April 1991. The event offered a forum for sharing “the LFM Way” — what the program has learned during the past three years — with leaders from industry and academia, as encouragement to other universities and companies to institute or join programs similar to LFM, or re-direct existing programs. More than 400 individuals attended, representing more than 80 firms, almost 60 universities, and about 10 government organizations. Later, in June, the Leaders Program assisted with the 1991 Operations Management Workshop, bringing together faculty from many of the leading business schools and several leading practitioners from industry, and hosted a two-day conference funded by the Sloan Foundation focusing on manufacturing curricula (*see the Curriculum section of this report*).

The program’s working papers library has expanded to more than 100 papers, including theses of fellows and research assistants.

The LFM fellows this past year offered greater leadership in program functioning. The Class of 1992 performed a total quality management analysis on the program; as a result, fellows have greater leadership roles in program committees and key activities (e.g., internship projects, admissions, a seminar series of invited chief executive officers). The class also assumed responsibility for designing and structuring the required Proseminar during the spring, to focus on leadership. Student recommendations have also led to broader program review sessions with the fellows, to foster greater student input into the program’s functioning.

H. KENT BOWEN
THOMAS L. MAGNANTI

Materials Processing Center

The year 1990 marked an important event for the Materials Processing Center (MPC) – its tenth anniversary. Founded in 1980 with a NASA grant to establish a research base in materials processing, the MPC has since expanded to a current annual research budget of \$7 million. In leading the center into the 1990s, former director Ron Latanision and his colleagues have developed a framework that focusses on a number of national priorities: the need to preserve the environment, energy resources, a strong national defense, and a competitive industrial base, as well as to develop America's human resources at every stage in the educational continuum.

The MPC is now under new leadership – Professor Thomas W. Eagar, an internationally recognized expert on the physics and chemistry of welding and other metal-joining processes, is the director as of July 1st. The center will continue to provide both an interdepartmental focus on a broad range of materials and materials processing research at MIT and an international forum for the scientific information and technology transfer necessary to advance materials processing technologies

The MPC, an interdepartmental center, reports to the Dean of the School of Engineering, Professor Joel Moses.

INTERDISCIPLINARY, FUNDAMENTAL RESEARCH

Through processing, one can control a material's internal structure on both the macroscopic and the microscopic level, thus influencing its properties and performance. The founding premise of the MPC is that processing for control of structure must be based on scientific fundamentals, rather than the empiricism of years past.

A theme common to MPC projects is the interdisciplinary nature of the research. Projects typically involve a number of faculty, staff, and students from several departments, including Chemical Engineering, Civil Engineering, Physics, Nuclear Engineering, Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemistry.

A more detailed description of research activities can be found in the *Materials Processing Center Report on Research*. This volume is available from the MPC headquarters in Building 12-007.

EDUCATION: DEVELOPING AMERICA'S HUMAN RESOURCES

One MPC goal has been to increase the number of materials processing students and practicing professionals. We agree with the recent National Research Council report on materials science and engineering that our nation must remedy its serious weakness in materials processing and synthesis. In particular, our nation must translate scientific promise into commercial success; in other words, it must promote process technology. However, the National Science Foundation projects a shortfall of engineers and scientists over the next two decades. The MPC believes it is crucial to encourage students to develop processing skills.

Fellowships and Summer Scholarships

The MPC, through its Collegium, has sponsored 58 graduate student fellowships and 43 undergraduate summer scholarships. The summer scholarship program, established in 1983, seeks to attract undergraduate students from a variety of disciplines to the opportunities available in a career in materials processing. For the summer of 1991, the center awarded three summer scholarships to juniors enrolled in ceramics engineering, chemical engineering, and mechanical engineering in universities throughout North America. During the summer, these undergraduates participate in ongoing or new materials processing research programs. They then return to their respective schools in the fall to complete their undergraduate programs, carrying with them a valuable experience and the clear message that materials processing is a rewarding field within which math, chemistry, physics, and other engineering students can apply their talent.

Similarly, the fellowship program, begun in 1982, endeavors to attract the very best entering graduate students to materials processing. For the 91/92 academic year, the MPC offered four fellowships to students in

the Chemical Engineering, the Department of Materials Science and Engineering, and the Program in Polymer Science and Technology.

High School Outreach Program

Over the past few years, the center has expanded an innovative program that exposes outstanding Massachusetts high school students to the rewards of basic scientific research and engineering here at MIT. Since 1987, more than 700 students and their teachers have visited MIT to tour the materials processing research labs. These tours introduce students not only to materials processing research, but to the impact of science and technology on society and public policy as well. By reaching out to students at a time in their lives when they are formulating their goals for the future, the MPC hopes to encourage them to pursue careers in science or engineering.

Science and Engineering Program for High School Teachers

In 1990, the MPC had its most successful Science and Engineering Program for High School Teachers ever – 58 teachers attended from New England and several other states, including Hawaii. Professor Latanision, in his address to the MIT Alumni Leadership Conference last September, pointed out that teachers are the key to catalyzing student interest and enthusiasm for science. Students continually flow through the academic system, but the teachers are a constant, perennial resource for their students and schools. In subsequent presentations to MIT alumni clubs throughout the nation, Professor Latanision and his staff urged club members to encourage their local teachers to apply. As a result, several clubs and individual alumni sponsored teachers from elementary, middle, and secondary schools in their areas. During the one-week program, they joined their New England counterparts and explored how engineers apply basic scientific principles to meet the technological challenges and needs of commerce and society.

Immediately following the program was a meeting of the New England Science Teachers (NEST), a pro-active group that emerged from the program's first-year participants. NEST membership has grown and now includes members from all three years of the program. NEST members are developing a position paper that identifies recommendations and actions they consider necessary to reverse the existing decline in science literacy and engineering enrollment in the United States.

COLLABORATION WITH INDUSTRY

The MPC believes that due to the rapid rate of scientific and technological innovation, new mechanisms must be developed to facilitate the transfer of scientific information and technology to industry in ways that go beyond the traditional modes of research publication and student graduation. Collaboration with industry is critically important to the university, providing academic programs with the long-term direction necessary to maintain a high degree of relevance to rapidly evolving research needs.

Since its inception, the center has encouraged a close working relationship with industry through its industrial advisory board, industry collegium, and multi-client research consortia. The board, which has 23 members, annually reviews ongoing MPC research programs and policies. The collegium, now with 70 corporate member companies worldwide, encourages close contact between industrial representatives and MPC personnel through seminars, visits, and tours of the research facilities. Person-to-person contact between visiting scientists and engineers from these companies and center faculty, staff, and students encourages the flow of creative ideas in both directions. At the same time, it provides excellent opportunities for bilateral information and technology exchange. Over the past few years, the center has had more than 35 visiting scientists and engineers in residence. The MPC strongly encourages US industries to participate. Foreign participants are also accepted, and they assist in keeping our faculty, staff, and students up-to-date with the state-of-the-art in off-shore materials research.

The MPC adopted the consortia, or multi-client sponsored research concept, in 1980 to promote collaborative, generic materials processing research. The newest of these, the MIT Electronics Packaging Program, is a multi-investigator effort that focusses on a specific research vehicle, in this case a metal-polymer multilevel high-density-interconnect chip carrier, to investigate a number of critical materials aspects of electronic packaging: photosensitive polymers, plasma modification of the polymer-metal interface, polymer metal adhesion, electrochemical and corrosion studies of the polymer metal system, and fatigue and fracture in

multilevel, interconnect structures. Through groups such as these, the center strengthens the link between basic research at the university and innovation in industry.

INFORMATION EXCHANGE

Last year, the MPC celebrated its tenth anniversary with a symposium entitled "Materials Processing in the 1990s: MPC Tenth Anniversary Symposium." Speakers from center faculty and staff, from government, and from industry presented their respective views of future materials research and development needs and priorities. Symposia like this provide speakers, center staff, and attending industrial representatives the opportunity to exchange and disseminate research results.

NEW DIRECTIONS

The MPC faces many exciting opportunities in the coming years. A recent National Research Council report, *Materials Science and Engineering in the 1990s: Maintaining Competitiveness in the Age of Materials*, identifies materials synthesis and processing as a major national research thrust for the next decade and beyond. The field of materials synthesis and processing is now recognized as an emerging technology critical to both industrial and international competitiveness. The NRC study, which was cochaired by Professor Mert Flemings, the founder of the MPC, has inspired a number of center proposals in materials synthesis and processing research that emphasize a multidisciplinary and multi-investigator approach. The MPC, now under the leadership of Professor Eagar, expects to expand current research initiatives and to start new ones in areas such as net-shape processing, intelligent processing, environmentally sound processing, electronic packaging, processing of opto-electronic materials, and processing in high magnetic fields.

The MPC, through its direct interaction with industrial personnel, promotes the technology transfer upon which innovation in materials processing is based. For the past eleven years, the center has provided a focus and forum in which academic, industrial, and government personnel can broaden their knowledge while collaboratively developing new scientific and technological skills in materials processing. Through such collaboration and cooperation, we expect to exercise our leadership role in the evolution of new materials, the development of the processing technologies required to manufacture with these materials, and, ultimately, to transfer materials processing know-how into the worldwide marketplace.

R.M. LATANISION

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

This year the School of Humanities and Social Science continued to focus its efforts on fund-raising, curriculum reform, affirmative action, and faculty recruitment in departments and sections which are experiencing a significant number of retirements and resignations. The faculty within the School continued to receive a number of honors and awards, and some important administrative changes within the School have occurred.

Undergraduate Education

The Humanities, Arts, and Social Science-Distribution (HASS-D) system is now fully implemented, with the last graduating class under the previous HUM-Distribution system having completed their S.B. degrees this year, June 1991. There will be 74 HASS-D subjects offered in 1991-92, which represents an increase from the 68 offered in 1990-91. Since this number is right at the target number of 75 HASS-D subjects, the goal for the future will be to keep this number approximately stable, although some courses will be phased out and new ones added. The HASS-D Language Option -- allowing students to substitute either a Level III or a Level IV foreign language subject for one of their three required HASS-D subjects -- was successfully implemented in 1990-91. Also during 1990-91, the HASS-D Overview Committee conducted the three-year interim review of the HASS-D system which was mandated when the new distribution system was decided upon. The review included two open forums, where HASS faculty had the opportunity to air their views and discuss the requirement with their colleagues and Acting Dean Philip S. Khoury. Minor changes affecting the final examination requirement and the writing component will be recommended to the CUP in the fall.

The HASS Minor, an intermediate option between the HASS concentration of three or four subjects in a given field and the HASS major, is proving to be increasingly popular. By the end of 1990-91, 443 students were registered as candidates for a Minor in one of 19 available Minor programs, compared with 352 students in 17 programs in 1989-90 (14% of the Class of 1991 graduated with minors). Two new Minors were introduced in 1990-91: in Film and Media Studies and in the History of Art and Architecture. Although no new Minor programs were approved for 1990-91, proposals for additional Minor programs in regional studies are in preliminary stages.

As a result of an MIT faculty vote in spring 1989, June 1991 Course XXI majors were the second class to graduate with degrees that designate their specific fields. Thirty-one students receiving Course XXI degrees in June 1991, including 16 who completed joint degrees with science or engineering. The total number of undergraduate majors in the School continues to increase, due mainly to the growing numbers in Economics (111 in 1989-90 and 115 in 1990-91), and the Humanities (51 in 1989-90 and 64 in 1990-91).

New Initiatives

The Cultural Studies Project has begun to achieve its first goal of establishing itself as a visible presence within MIT and beyond. During its first year this interdisciplinary project sponsored two national conferences ("Epidemics: Perspectives in Cultural Studies" and "Melodrama Across Cultures"), established a Biographers' Roundtable and laid the groundwork for a range of future activities which will include a Working Paper series and a Visiting Scholars program. This project has been supported with funds from the Provost and the Dean and is directed by Professor David Thorburn of the Literature Faculty. The project already has the active participation of faculty from the seven sections and programs that comprise the Humanities at MIT.

Foreign Languages and Literatures, with the assistance of a grant from the Chiang Ching-kuo Foundation, continues to expand their East Asian component with the establishment of a Chinese Language, Literature and Culture Program. Coordinated by Visiting Assistant Professor Yih-jian Tai, an expert on Classical Chinese Drama, the program will offer Beginning Chinese as well as Chinese Literature in translation in 1991-92.

The past year saw the signing of a Memorandum of Understanding between the Dibner Fund and MIT that lays the groundwork for the location at MIT of the Dibner Institute for the History of Science and Technology and the Burndy Library. Details of the arrangements will be announced when an Affiliation Agreement has been completed. Plans are underway for the

renovation of MIT Building E38 (56 Memorial Drive), which will house the Dibner Institute and the Burndy Library in addition to a variety of Sloan School activities. A search is underway to fill the dual post of Dibner Professor in the History of Science and Director of the Institute.

Affirmative Action

The affirmative action record of the School of Humanities and Social Science appears to be strong relative to the rest of the Institute mainly because the representation of women within the fields of humanities and social science is relatively large. The School's record relative to the pool, however, is about average. Within the School there are 30 women faculty, which represents 20 percent of the total. Of these 21 are tenured (18 percent of the tenured faculty). Over the past five years, the total number of women faculty has remained essentially constant. However, we are looking forward to an increase in these numbers owing to the Provost's new program to attract women faculty to MIT.

The School's record with respect to underrepresented minority faculty is much less satisfactory than it is with respect to women. There are currently three tenured minority faculty and one untenured minority faculty within the School. In 1990-91, two offers were made to members of underrepresented minorities; one by the Literature Faculty and the other by the History Faculty. The History Faculty's offer has been accepted and the number of untenured underrepresented minorities will have increased by one. The School remains committed to increasing the number of minority faculty members. To this end, the departments and sections within the School may not go forward with search plans without the determination of the relevant pool of minority appointments. Moreover, the Dean has encouraged certain departments and sections to make appointments in fields in which significant numbers of underrepresented minorities are known to be involved.

Honors and Awards

The faculty within the School of Humanities and Social Science garnered an impressive array of honors and awards this year. The most notable among them were the following: Professors Jerry Hausman and Paul Joskow of the Department of Economics were elected Fellows of the American Academy of Arts and Sciences. In addition the Academy elected as Fellows Visiting Professor Jill Conway and Professor Merritt Roe Smith of the Science, Technology and Society Program, and incoming Professor John W. Dower of the History Faculty. Professor Smith was also elected a member of the Section for History and the Philosophy of Science of the American Association for the Advancement of Science. Professor Thomas Kuhn of the Department of Linguistics and Philosophy received an honorary degree (Doctor of Letters) from Columbia University. Professor John Harbison of the Music and Theater Arts Section was selected as Mary Biddle Lecturer at Duke University and was appointed to the Board of Trustees of the American Academy in Rome. Professor Harvey Sapolsky of the Political Science Department was elected a fellow in the National Academy of Social Insurance. Professor Paul Krugman of the Department of Economics won the bi-annual John Bates Clark Medal for the best economist under 40 and also won the Eccles Prize for excellence in economics writing; and Professor Jean Tirole was elected council member of the Econometric Society. Associate Professor Richard Valelly of Political Science received a fellowship from the W.E.B. DuBois Institute for Afro-American Research. Professor Stephen Tapscott of the Literature Section was awarded a fellowship at the Virginia Center for the Creative Arts and was also a recipient of the Gyorgy Kepes Prize for the Arts. The Department of Political Science's Associate Professor Barry Posen was awarded the Levitan Prize in the Humanities for his project on nationalism and war, and Professor Willard Johnson received a Distinguished Scholarship Award from the University of Massachusetts at Boston. Book prizes went to the Writing Program's Professor Alan Lightman (the Association of American Publishers Award for the most outstanding book in physical science for 1990) for his book entitled *Origins: The Lives and Worlds of Modern Cosmologists* (Harvard University Press, 1990), and Associate Professor Harriet Ritvo was one of ten American writers to receive a Whiting Writers' Award given in recognition of outstanding literary accomplishment. Assistant Professor Jeffrey Wooldridge of the Department of Economics was named an Alfred P. Sloan Research Fellow, and Assistant Professor Roland Benabou was a National Bureau of Economic Research (NBER) Research Fellow. Professor Richard Cartwright of the Department of Linguistics and Philosophy received the Distinguished Achievement Award from Brown University, and the Department's Professor Noam Chomsky was the recipient of the Institute's James R. Killian Faculty Achievement Award. In 1991-92,

Professor Michael Piore of the Economics Department will become the next David W. Skinner Professor of Political Economy; Associate Professor Arthur Steinberg of the Program in Anthropology/Archaeology will become the first Class of 1960 Fellow; and Professor Kenneth Manning will be the next holder of the Thomas Meloy Professorship in Rhetoric; The Department of Economics will bring Janet Currie as an Assistant Professor of Labor Economics, who has been awarded the Pentti J.K. Kouri Career Development Chair for two years.

Fundraising

As MIT's Campaign for the Future entered its fourth year, the School continued its efforts to raise funds from foundations, corporation and individual donors. Foundations continue to be a major source of support, especially in the area of the social sciences. This year we were able to complete a 2:1 match for a \$1.5 million grant from the Ford Foundation for graduate fellowships in the Defense and Arms Control Program. A \$5 million grant from the Knight Foundation for the Knight Science Journalism Program is still in the process of being matched on a 1:2 basis. The Foreign Languages and Literatures Section received a \$179,520 grant from the Chiang Ching-kuo Foundation for the development and initiation of a Chinese Language Program. The Chinese Alumni of MIT (CAMIT) has agreed to support a five-year effort to raise an endowment which would put the Program on a permanent footing.

The US-Japan Program, directed by Professor Richard Samuels, has been the main recipient of corporate funding, with support coming from IBM, AT&T, GE, and other major American companies. Japanese financial institutions were solicited for membership in the new World Economy Laboratory located within the Department of Economics. This effort represents the first stage in a plan to raise funds for the School from Asian sources, primarily those in Japan, Hong Kong, Taiwan, and Singapore. One or more trips are scheduled for these areas over the coming year by the Dean, the Assistant Dean for Development, and members of the faculty.

Efforts to raise funds from the School's relatively small pool of alumni met with modest success. A number of gifts and pledges in the \$25 to 50K range were received. These were the result of ongoing cooperative efforts by SHSS's development office and MIT's central development office. Thanks in large part to the work of Helmut Weymar (58 MG), funding for a chair in honor of Paul A. Samuelson was nearly completed. A priority for the coming year will be the continuation of cultivational events for School alumni and alumni of the four other MIT Schools.

Administrative Changes, Retirements

This year has seen a number of retirements and new appointments within the School. The following faculty members will retire as of June 30, 1991: Professor Lincoln Bloomfield of the Department of Political Science, Professors Richard Douglas and Harald Reiche of the History Section, Professor Stephen Erderly of the Music and Theater Arts Section, and (effective August 30, 1991) Professor Thomas Kuhn of the Department of Linguistics and Philosophy. We wish them great success in all their future endeavors as emeriti professors of MIT.

Effective July 1, 1991, Professor Kenneth Manning will step down as Head of the Writing Program, and Professor Alan Lightman will replace him. We will miss the insights and administrative wisdom of Professor Manning and wish him well as he returns to a professional life focused on scholarship and teaching.

Professor Philip S. Khoury of the History Faculty has been appointed Dean of the School of Humanities and Social Science, after serving as Acting Dean in 1990-91, and Associate Dean of the School between 1987-90. Other changes in the Dean's office staff include the appointment last October of Ms. Elisabeth Stark as Administrative Secretary.

PHILIP S. KHOURY

TABLE I
ENROLLMENT IN HUMANITIES, ARTS, AND SOCIAL SCIENCE SUBJECTS:
1990-91

Field	Elective Subjects		Hum-Distribution		HASS-Distribution		Totals	
	# of Subjects	# of Students	# of Subjects	# of Students	# of Subjects	# of Students	# of Subjects	# of Students
Anthropology/ Archaeology	17	134	1	28	4	95	22	257
Economics	17 ⁴¹	1261	1	41	1	13	19 ⁴³	1315
Foreign Lang & Literature	57 ⁸²	856	2	42	21 ³⁹	495	80 ¹²³	1393
History	26	318	9	68	10	386	45	772
History of Art & Arch	2	21	1	16	3	87	6	124
Linguistics	1	22	1	35	0	0	2	57
Literature	26	320	2	43	23 ³⁶	860	51 ⁶⁴	1223
Music	18 ²⁴	373	1	9	7 ²⁰	404	26 ⁴⁵	786
Philosophy	18	224	0	0	7	269	25	493
Political Science	21	220	1	4	9	272	31	496
Psychology	8 ⁹	368	0	0	1	444	9 ¹⁰	812
STS	15	62	2	29	4	106	21	197
Theater Arts	10 ¹¹	120	0	0	5	41	15 ¹⁶	161
Urban Studies	2	37	3	50	4	80	9	167
Visual Arts	7	55	0	0	2 ⁴	94	9 ¹¹	149
Women's Studies	8	42	0	0	4	56	12	98
Writing	27 ⁵⁹	468	6 ¹¹	126	3 ⁷	126	36 ⁷⁷	720
TOTALS	280 ³⁶⁹	4901	30 ³⁵	491	108 ¹⁵⁸	3828	418 ⁵⁶²	9220

Note: Figures were obtained from the grade/subject distribution report which shows the final tally for each class. The numbers shown are for undergraduate subjects which normally satisfy the HASS Requirement; they do not include subjects allowed towards the Requirement only upon petition. Superscript is the number of autonomous class sections if more than one; this does not apply to subjects which meet in a single lecture once or twice a week and divide into discussion sections for a single meeting. Enrollment figures appear lower than last year's because accurate, end-of-term figures were used instead of those from the fifth week of the term.

TABLE II
CONCENTRATIONS IN ALL FIELDS OF HUMANITIES,
ARTS, AND SOCIAL SCIENCES*
JUNE 1991

Fields of Concentration	Class of 1994	Class of 1993	Class of 1992	Class of 1991	Totals in Fields
American Studies	(0) 0	(0) 0	(5) 2	(8) 8	(13) 10
Ancient & Medieval	(0) 0	(2) 0	(4) 0	(6) 5	(12) 5
Anthropology/Archaeology	(1) 0	(11) 0	(11) 2	(10) 9	(33) 11
Economics	(1) 0	(121) 9	(150) 40	(210) 193	(482) 242
Ethnic Studies	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0
Film & Media Studies	(0) 0	(4) 0	(8) 1	(3) 3	(15) 4
Foreign Languages**	(9) 0	(88) 10	(129) 45	(181) 164	(407) 219
History	(0) 0	(13) 0	(38) 16	(77) 75	(128) 91
History of Art	(0) 0	(4) 0	(14) 5	(6) 6	(24) 11
Labor in Industrial Society	(0) 0	(0) 0	(0) 0	(1) 1	(1) 1
Latin American Studies	(0) 0	(1) 0	(1) 0	(0) 0	(2) 0
Linguistics	(0) 0	(2) 0	(4) 1	(2) 2	(8) 3
Literature	(0) 0	(34) 2	(41) 12	(86) 84	(161) 98
Music	(0) 0	(48) 0	(70) 6	(103) 95	(221) 101
Philosophy	(0) 0	(17) 0	(21) 13	(51) 49	(89) 62
Political Science	(0) 0	(20) 4	(36) 12	(53) 53	(109) 69
Psychology	(0) 0	(25) 3	(49) 4	(107) 92	(181) 99
Russian Studies	(0) 0	(2) 1	(5) 1	(5) 5	(12) 7
Science, Technology, & Society	(0) 0	(9) 0	(6) 0	(11) 10	(26) 10
Theater Arts	(0) 0	(10) 1	(7) 2	(8) 7	(25) 10
Urban Studies	(0) 0	(2) 0	(1) 0	(12) 9	(15) 9
Visual Arts & Design	(1) 0	(2) 0	(1) 0	(11) 7	(15) 7
Women's Studies	(1) 0	(4) 0	(4) 3	(15) 14	(24) 17
Writing	(0) 0	(15) 0	(38) 6	(74) 64	(127) 70
<u>Special Concentrations</u>	<u>(2) 0</u>	<u>(3) 0</u>	<u>(10) 4</u>	<u>(19) 17</u>	<u>(34) 21</u>
TOTALS	(15) 0	(437) 30	(653) 175	(1059) 972	(2164) 1177

* The parenthetical figure is the number of proposed concentrations in the given class and fields; the figure to its right is the number of these concentrations that have been completed.

** Figures for subfields of Foreign Languages and Literatures:

ESL	(0) 0	(0) 0	(3) 0	(3) 2	(6) 2
French	(0) 0	(19) 0	(28) 10	(53) 50	(100) 60
German	(9) 0	(21) 4	(26) 7	(31) 29	(87) 40
Japanese	(0) 0	(9) 0	(17) 5	(18) 16	(44) 21
Russian	(0) 0	(13) 2	(15) 6	(17) 15	(45) 23
Spanish	(0) 0	(24) 4	(29) 16	(36) 30	(89) 50
Other Languages	(0) 0	(1) 0	(7) 1	(12) 11	(20) 12
World Literature	(0) 0	(1) 0	(4) 0	(11) 11	(16) 11

TABLE III

Undergraduate Majors in the School of Humanities and Social Science

Year	Economics	Humanities*	Philosophy	Pol Science	Total
1981-82	51	49	9	32	141
1982-83	48	37	7	28	120
1983-84	48	24	3	22	97
1984-85	52	30	2	15	99
1985-86	51	52	5	26	134
1986-87	49	57	7	21	134
1987-88	76	77	9	40	202
1988-89	103	52	11	43	209
1989-90	111	51	13	54	229
1990-91	115	64	13	44	236

*These figures do not include double majors who registered first in a course other than Humanities. (If you include double majors, the figure is 93.)

TABLE IV

Graduate Students in the School of Humanities and Social Science

Year	Economics	Hist & Soc Study of Sci & Tech	Linguistics & Philosophy	Pol Science	Total
1981-82	111	- -	55	142	308
1982-83	136	- -	51	163	350
1983-84	113	- -	52	99	264
1984-85	108	- -	53	121	282
1985-86	130	- -	59	171	360
1986-87	105	- -	55	115	275
1987-88	120	- -	72	157	349
1988-89	127	4	67	118	316
1989-90	132	9	77	154	372
1990-91	134	13	61	154	362

TABLE V
HASS MINOR APPLICATIONS
FOR CLASSES OF 1991, 1992, 1993, AND 1994

FIELD	TOTAL APPLICATIONS
Anthropology/Archaeology	6
Economics	123
*Film and Media Studies	9
French	14
German	22
History	20
*History of Art and Architecture	5
Literature	41
Music	60
Philosophy	6
Political Science	31
Psychology	37
Russian	9
Science, Technology, and Society	1
Spanish	16
Theater Arts	11
Urban Studies and Planning	0
Women's Studies	8
Writing	24
TOTAL	<u>443</u>

* = new Academic Year 1990-91

Humanities, Arts, and Social Sciences Office

The HASS Office continued to serve multiple functions, including the administration of the eight-subject HASS requirement, the HASS Minor, the Harvard Cross-Registration Program, provision of statistics for the School of Humanities and Social Science, and the publication of the HASS Guide each term. This office has the responsibility, on behalf of the Registrar's Office, of recording proposal and completion forms for both concentrations and minors on each student's record. Petitions for HASS credit for subjects which are not so coded, such as Harvard and Wellesley subjects, graduate subjects, etc., are submitted here for approval. Information concerning any of the above, as well as HASS transfer credit and general Institute information, was provided to the MIT community and in response to inquiries from outside the Institute.

A complete change in personnel occurred during the past year, with Dr. Bette Davis replacing Ms. Ruth Spear as Coordinator, and Ms. Eileen Murray taking on the position of part-time Senior Secretary.

HASS ENROLLMENT STATISTICS BY FIELD AND SUBJECT - - RECENT TRENDS

The number of HASS subjects offered in 1990-91 increased from 403 to 418, with the number of autonomous sections increasing from 533 to 562. The overall enrollments in Table I appear to be lower than last year's only because accurate, end-of-term figures were used instead of those from the fifth week of the term, which have been used previously. As expected, with the phasing out of the HUM-D system, the numbers of both HUM-D subjects and enrollments in those subjects decreased greatly (from 48 to 30 and 1001 to 491, respectively). Offsetting this, however, was an increase in the number of HASS-D subjects and sections and in the number of students taking those subjects. (There were 108 HASS subjects, compared with 88 in 1989-90, and 158 autonomous sections compared to 121 the previous year. The increase in HASS-D enrollments is actually greater than the 3586 to 3828 shown because of the data used, as explained above.) The largest overall enrollments were in Foreign Languages and Literatures (1393), followed by Economics, with 1315, and Literature, with 1223. Fields that showed growth in enrollments were Anthropology/Archaeology, History, Theater Arts, and Visual Arts.

HASS CONCENTRATIONS: PATTERNS OF POPULARITY

Economics was once again the most popular field of Concentration, followed by Foreign Languages and Literatures, Music, and Psychology. There are 482 proposed concentrators in Economics, followed by 407 in Foreign Languages and Literatures, 221 in Music, and 181 in Psychology. Economics also has the greatest number of completed concentrations, with 242, followed by Foreign Languages and Literatures, with 219. Music, Psychology, and Literature have nearly equal numbers of completed concentrations - - 101, 99, and 98, respectively. There were 124 more proposals filed this year than last, with the increase almost entirely in the sophomore and junior classes. Again this year, a reminder was sent to all sophomores that concentration proposals should be filed by the end of the sophomore year.

HASS MINOR PROGRAMS

In its third year, the HASS Minor Program is increasingly popular; the number of candidates for one of the 19 possible minors grew from 352 to 443 in the past year. The four most popular fields were the same as last year, in the same order: Economics (123), Music (60), Literature (41), and Psychology (37).

HARVARD CROSS-REGISTRATION

There was a 15 percent increase from last year in the number of students taking subjects at Harvard: 217 students taking 238 subjects, compared to 189 students taking 204 subjects in 1989-90. Italian was the most popular field, with 23 MIT undergraduates taking that language, compared to 11 last year. There was also a great jump in the enrollment in Art/Visual Studies, from eight to 20 in the past year. Korean (19) was the next most popular field, followed by Chinese, with 17. (That number dropped from 33 the previous year, probably in anticipation of Chinese being offered at MIT in 1991-92.)

COURSE XXI DEGREES GRANTED

Three students received their S.B. in Humanities in February 1991 (1 in XXI-M, Music; 1 in XXI-E, and 1 in XXI-S); 31 students received the S.B. in June 1991, for a total of 34. Of the June graduates, 16 received joint degrees, 10 in XXI-E and 6 in XXI-S. In the second year that the specific field within Course XXI could be designated on the degree, 12 students received degrees in their specific fields, including six in Music and 4 in Literature. Three generic XXI degrees were granted in June 1991.

COURSE XXI ENROLLMENT

In May 1991 there were 93 students who had declared a major in Course XXI. Of these, 42 were joint majors (23 in XXI-E and 19 in XXI-S), and 29 had joint majors. The distribution of these students into the specific fields within Humanities remained basically constant, with Literature dominant, followed by Writing and Music.

COURSE XXI HONORS AND AWARDS

Among the more notable distinctions and honors achieved by Course XXI students this year were:

Phi Beta Kappa: Daniel A. Schmidt '91
 Burchard Scholars: John Ito '93, Rajiv Suri '92, Eric Zylstra '92
 I. Austin Kelly III Competition: Joseph Powers, Jr. '92
 William Eugene Edgerton Award: David Oh '91
 Ragnar and Margaret Naess Music Fund Scholarship: Erika Anderson '91
 Rhodes Scholarship: Darcy Prather
 Robert A. Boit Writing Prize: Dean Miller '91
 Boit Manuscript Prize: Eric Colburn '91, Yu Hasegawa '91, Lincoln Ross '91
 Victor Tulli '91
 Malcolm G. Kispert Award: Darcy Prather

PHILIP S.KHOURY

Department of Economics

INTRODUCTION

The scientific activities of the Economics Department continued at an intensive pace during the year. Members of the faculty also extended their involvement with national and international policy issues on a number of fronts. Although no new senior appointments were made this year, four junior faculty appointments were made in several areas. The Department also continued to be unusually successful in recruiting graduate students in competition with other leading departments.

FACULTY PERSONNEL

The Department was fortunate this year having four offers of appointment accepted by fine young economists. Andrew Bernard, who has just graduated from Stanford University, will be working in macroeconomics and econometrics. David Genesove, who received his Ph.D. from Princeton University, will be working in industrial organization and applied economics. Lones Smith, from the University of Chicago will provide needed support in theory. The Department is pleased to report its Affirmative Action efforts resulted in the appointment of Janet Currie who comes to us from the Department of Economics at the University of California, Los Angeles and will add strength to the labor economics group. Professor Currie has been appointed to the Kouri Career Development Chair.

Assistant Professor Jeffrey Wooldridge was granted promotion to the rank of Associate Professor effective July 1, 1991, but unfortunately has resigned from the Department to accept an offer from Michigan State University. The Department has also accepted, with regret, the resignations of Professor Daniel McFadden who will return to the University of California, Berkeley, Professor Henry Farber who has accepted a position at Princeton University, Associate Professor Robert Gibbons who will be joining the Department of Economics at the Johnson Graduate School of Management at Cornell University, and Assistant Professor Andrea Shepard who has accepted a position at the Stanford Business School.

Professor Richard Eckaus completed his three year term as department head and was replaced by Professor Peter Temin. Professor Ann Friedlaender completed her tenure as Dean of the School of Humanities and Social Science and rejoined the Department as a faculty member on leave this year. Other senior faculty members on leave for the year or part of the year were Professor Olivier Blanchard, Professor Jerry Hausman, Professor Michael Piore, Professor James Poterba, Professor Richard Schmalensee, Professor Lance Taylor, and Associate Professor William Wheaton. Two junior faculty members, Professor Gibbons and Professor Shepard were also on leave, conducting research at the National Bureau of Economic Research and Harvard University, respectively.

There were four visiting faculty during the year: Assistant Professor Christopher Harris of Nuffield College, Oxford University, Professor Laurence Kotlikoff of Boston University, Associate Professor Paul Ruud from the University of California, Berkeley, and Winifred Rothenberg of Tufts University. Drazen Prelec of the Harvard Business School was an Assistant Professor for the Fall term whose visit was supported by the Sloan Foundation; he gave a series of seminars covering psychological theories in economics.

Robin Wells continued her post doctoral appointment from last year through the Fall term and then accepted a position at the University of Michigan.

The Department maintains its concern with increasing the representation of women and minorities in the economics profession. Although we have hired a woman junior faculty member, our entering graduate class had half as many women entrants as the previous year. The Department did have a visiting assistant professor this year who was a woman and will have an Indian female professor on the staff for the next year.

STUDENT RECRUITMENT AND ENROLLMENT

The recruitment of graduate students continued to be highly competitive with other major graduate programs. The leading applicants for admission were again invited to visit the Department, as is now done by all of the top graduate economics departments. This year about 40 per cent of the U.S. students receiving National Science Foundation fellowships to begin their graduate studies in economics elected to come to this Department, almost three times the percentage of any other economics department.

Undergraduate enrollments continued to climb rapidly, although at a slightly reduced pace from the previous year. There were 115 undergraduate majors in economics by the end of the year, which is a small increase over the previous year and a 46 percent increase over 1988-1989; the number of minors continued to grow with 127 registered this year. The total enrollment in all undergraduate subjects in Economics this year was 6 percent larger than last year and 35 percent larger than in 1988-1989. While these increases are gratifying, they have substantially increased the teaching burden in the Department.

FACULTY RESEARCH

Faculty research continues to be intensive and productive. Following are examples: "Inflation and Efficiency in Search Markets", (Assistant Professor Roland Benabou); "The Macroeconomic Implications of the New Forms of Labor Contracts," (Professor Blanchard); "Inventories and Money Holdings in Search Equilibrium," (Professor Peter Diamond with Joel Yellin); "Priorities of Economic Reform in the Emerging Democracies," (Professor Rudiger Dornbusch); "Some Lessons From Development Economics for Southern and Eastern Europe," (Professor Eckaus); "The Role of Arbitration Costs and Risk Aversion in Dispute Outcomes," (Professor Farber with Margaret A. Neale and Max J. Bazerman); "Issues in Socialist Economy Reform," (Professor Stanley Fischer with Alan Gelb); "Normal Goods and the Expenditure Function," (Professor Franklin Fisher); "Repeated Games with Long-Run and Short-Run Players," (Professor Drew Fudenberg with D. Kreps and E. Maskin); "The New Economics of AIDS," (Associate Professor Jeffrey Harris); "Is 'Bounded Rationality' an Important Element a Theory of Institutions?", (Professor Oliver Hart); "An Economic Analysis of International Joint Ventures in Telecommunications," (Professor Hausman); "The Diffusion of New Technology: Evidence From the Electric Utility Industry," (Professor Paul Joskow with Nancy Rose); "History and industry location: the case of the US manufacturing belt," (Professor Paul Krugman); "The Effect of Taxes on Occupational Choice: The Case of Irregular Labor Markets," (Assistant Professor Thomas Lemieux); "Corporate Reform in American Manufacturing and the Challenge to Economic Theory," (Professor Piore); "Are Japanese Stock Prices Too High?," (Professor Poterba with K. French); "The Relative Importance of Permanent and Transitory Components: Identification and Some Theoretical Bounds," (Assistant Professor Danny Quah); "Subjective vs. Objective Interests in the Principle of Consumer Sovereignty," (Professor Jerome Rothenberg); "Fiscal Issues in Macroeconomic Stabilization: A Structuralist Perspective," (Professor Lance Taylor); "Socialism and Wages in the Recovery from the Great Depression in the US and Germany," (Professor Temin); "Privatization and Incentives," (Professor Jean Tirole with Jean-Jacques Laffont); "Vacancy, Search, and Prices in a Housing Market Matching Model," (Professor Wheaton); "Specification Testing and Quasi-Maximum Likelihood Estimation," (Professor Wooldridge).

FACULTY HONORS

Professor Benabou was a National Bureau of Economic Research (NBER) Research Fellow. Professor Fischer was a member of the American Economic Association. Professor Fudenberg was the Plenary Speaker at the 1990 World Congress of the Econometric Society. Professor Hausman and Professor Joskow were elected Fellows of the American Academy of Arts and Sciences. Professor Krugman won the John Bates Clark Medal for the best economist under 40 and also won the Eccles Prize for excellence in economics writing. Professor Piore was appointed to the David W. Skinner Chair in Political Economy. Professor Tirole was elected to council member of the Econometric Society. Professor Temin was vice president of the Economic History Association. Professor Wooldridge was named an Alfred P. Sloan Research Fellow.

FACULTY PROFESSIONAL AND PUBLIC ACTIVITIES

The Department's faculty continue to give many invited lectures, appear at conferences and perform many functions in professional groups and other public services. The following are only a few examples. Professor Dornbusch gave the Geary Lecture in Dublin, Ireland. Professor Eckaus organized a conference on Economics of Global Warming for Developing Countries, delivered lectures in Rome and New Haven, and was on several advisory committees. Professor Fischer was a member of the World Bank team in the Joint (IMF, IBRD, OCED, EBERD) Study of the Soviet Economy and is a consultant for the State Department on the economy of Israel. Professor Hart has been an editor of several journals as well as serving on various committees such as the Japan/US Business and Economic Studies Technical Symposium at New York University. Professor Joskow lectures widely and has given testimony before Congress and Regulatory agencies. Professor Piore is a member of the Governing Board, Institute for Labour Studies of the International Labour Organization in Geneva, and is a member of the Research Council at the Economic Policy Institute in Washington, D.C.

DEPARTMENTAL GIFTS AND RESEARCH GRANTS

The Department continues to receive substantial financial support from its alumni and friends. George and O'Bie Shultz endowed a fellowship fund for graduate students doing research for dissertations. Substantial grants for graduate student support were also received from Helmut Weymar and Howard Head.

The Department has established the World Economy Laboratory (WEL) in order to organize the varied research interests of the Department more effectively. Some of the issues the WEL will address are the international implications of US domestic adjustment in the 1990's, debt problems of developing, US-Japan trade relations, and implications of the new world capital market.

PETER TEMIN

Department of Humanities

Anthropology/ Archaeology Program

In 1990-91, the Anthropology/Archaeology Program continued developing several initiatives in teaching and research in collaboration with other groups in the Institute. Professors James Howe, Jean Jackson and Assistant Professor Lisa Rofel participated in the graduate program in the History and Social Study of Science and Technology, now completing its third year. The A/A Program's lecture series on "Peoples and States: Ethnic Identity and Struggle," co-sponsored by the Center for International Studies (CIS), with additional funding from the Office of the Dean of the School of Humanities and Social Studies (SHSS) finished a second successful year, lining up nine eminent anthropologists and political scientists for what promises to be an equally stimulating series in 1991-1992. Associate Professor Arthur Steinberg served a third year as director of the Integrated Studies Program, or ISP; after being very favorably evaluated, the program was renewed for 1991-92 by the Provost's Office. Professor Steinberg has become very involved in introducing ISP-like programs in the secondary school curriculum. In recognition of these and other contributions reflecting his commitment to teaching and educational innovation, Professor Steinberg was selected as the first Class of 1960 Fellow. Professor Heather Lechtman and Assistant Professor Dorothy Hosler, who hold joint appointments in A/A and the Center for Materials Research in Archaeology and Ethnology (CMRAE) presented research results of their project "Style in Art and Technology: Precolumbian American and Precolonial Africa" in Washington, D.C. (please see CMRAE's President's Report for further information on this research).

Professors Martin Diskin, Jackson, and Howe all published articles in a book entitled Nation-States and Indians in Latin America. Professor Jackson published one other article on ethnic struggle in Colombia and has four articles in press. She served on an NEH Media panel in the fall. Professor Howe published another article, on missionaries among the San Blas Kuna, and has one article in press. He also served as consultant and translator in Panama for the British television production "Before Columbus." Professor Diskin published an additional article on food security in El Salvador. Professor Lechtman published one article on copper-arsenic ore smelting and has another in press. Professor Steinberg has an article on Venetian painting in press. Professor Lisa Rofel published an article on workers in post-Mao China and has another in press. Professor Hosler published an article on the development of ancient Mesoamerican metallurgy.

Five faculty members have books in progress. Professor Diskin was on leave this year, finishing a book manuscript on land reform in El Salvador. Professor Hosler, also on leave as an Old Dominion Fellow, signed a contract with MIT Press for her book The Sounds and Colors of Power in Ancient West Mexico. Professor Rofel's book, Imagined Modernities: Work, Gender and Identity in Contemporary China, will be published by University of California Press.

A/A faculty presented papers in Ontario, Amherst, Charleston, Mexico, Cuba, Washington, Santa Cruz, and New Orleans. Professor Diskin led a Smithsonian study tour of Central America and organized a trip to evaluate research sponsored by Oxfam America in four Central America countries. Professor Rofel spent one month in Hangzhou, China, and Professor Hosler made two trips to Mexico to gather data for her book.

Professors Diskin, Jackson, and Hosler received SHSS Dean's Fund awards to help with their research. Professor Hosler also received funding from American Smelting and Refining Company, and the John D. and Catherine T. MacArthur Foundation (via Jerome B. Wiesner).

Professor Hosler received HASS-D status for a revised introductory archaeology subject, and Professor Rofel taught an exciting new subject, "Gender and Technology" and secured HASS-D status for "Introduction to Anthropology." Two professors offered IAP activities.

The Program has been in contact with several potential target of opportunity candidates, but none to date fit well enough with the Program's teaching needs to warrant a formal petition to the administration regarding a new appointment. The A/A Program regrets to report that Professor Rofel has resigned from her position at MIT to assume a new post at U.C., Santa Cruz.

JEAN JACKSON

Foreign Languages and Literatures Section

Expanding the East Asian component of the Foreign Languages and Literatures program proved to be one of this year's most successful initiatives. The Section received a grant of \$180,000 from the Chiang Ching-kuo Foundation to initiate a Chinese Language, Literature and Culture Program at MIT. Professor Yih-jian Tai, an expert on Classical Chinese Drama, was appointed Visiting Assistant Professor of Chinese. Starting in fall 1991, he will coordinate this new initiative and will offer Beginning Chinese as well as Chinese Literature in translation. Also this year, Professor Shigeru Miyagawa, Chair of the Department of East Asian Languages and Literatures at the Ohio State University, the largest and most prestigious department of its kind in the United States, was appointed full professor in Foreign Languages and Literatures. Professor Miyagawa, an outstanding linguist, will provide distinguished leadership to the rapidly growing Japanese program.

Another emerging strength in Foreign Languages and Literatures is in the area of research in innovative approaches to interactive language learning technology. Having gained national and international recognition in this field, FL&L has maintained a substantial level of research support from a number of sources, including the Consortium for Language Teaching and Learning. Under the leadership of Senior Research Scientist Janet Murray, interactive videodisc projects created by Senior Lecturers Gilberte Furstenberg and Doug Morgenstern (French and Spanish), have received funds and equipment from sources such as: the National Endowment for the Humanities; the Florence Gould Foundation, and the Apple Computer Company. The following publications in the field of language pedagogy and technology are currently in press: Senior Lecturers Furstenberg and Morgenstern's "Technology for Language Learning and Teaching: Designs, Projects, Perspectives" (in Wilga River's Teaching Languages at College: Curriculum and Content), Dr. Murray's "Anatomy of a New Medium: Literary and Pedagogical Uses of Advanced Linguistic Computer Structures" (in Computers and the Humanities), and Lecturer Ellen Crocker's Neue Horizonte (D.C. Heath), a German language workbook and lab system (co-authored with David Dollenmayer).

In September, the new Language Learning & Resource Center opened in Building 20. The Center has satellite access to foreign television programs, two fully equipped audio/video classrooms, an expanded library of audio and video tapes, and a computer/video section consisting of terminals for access to the Athena Network and interactive video use. The facility has already proven to be a valuable asset to the entire MIT community.

A number of faculty members in Foreign Languages and Literatures continue to pursue research in literary and cultural studies and in linguistics. Associate Professor Isabelle de Courtivron's biography of Clara Malraux was accepted for publication (Editions de l'Olivier/Le Seuil) and will be published at the end of 1991. Her article on Clara and Andre Malraux and Modernist literary couples was accepted by the Kenyon Review. The following articles and edited volumes have been accepted and are presently in press: Professor Robert Jones's "Gogol and The French Absurdist" in Lecturer Elena Semeka-Pankratov's Essays in Poetics In Memory of Krystyna Pomorska (UCLA Slavic Studies). Lecturer Semeka's "The Sun and the Moon in Bulgakov's The Master and Margarita: Life, Death and Resurrection" (Semiotica) is also in press. Professor Edward Baron Turk's "Deriding the Voice of Jeanette MacDonald: Notes on Psychoanalysis and the American Film Musical" (Camera Obscura No. 25). Associate Professor Elizabeth Garrels's article on Maria Luisa Bombal "Ver y ser vista: La mirada falica en La ultima niebla" (Escritura); Associate Professor Margery Resnick's article on Carme Riera (Greenwood Press). Dr. Murray's reprint edition of Mary Taylor's Miss Miles was published by Oxford University Press (1990). In the field of linguistics, Professor James Harris published "The Exponence of Gender in Spanish," Linguistic Inquiry (1991), and "with Respect to Accentual Constituents in Spanish," in Campas, H. and F. Martinez-Gil (eds.), Current Studies in Spanish Linguistics, (Georgetown University Press, 1991). Professor Catherine Chvany published "The two-stem nature of the one-stem verb system: Another look at classes and exceptions," in the Slavic and East European Journal (1990), and "Verbal aspect, discourse saliency and the so-called 'perfect result' in modern Russian, in N.B. Thelin (ed.) Verbal aspect in discourse /Pragmatics and Beyond, (Amsterdam-Philadelphia: J. Benjamins) 1990. Associate Professor Suzanne Flynn published: "A Note in defense of a Parameter-Setting Model for Adult Second Language Acquisition: A Reply to Bley-Vroman and Chaudron '90" (with B. Lust) in Language Learning, (1990), and a chapter, "Theory, Research and Practice: Strange or Blissful Bedfellows?" in J. Alatis (ed) Theory, Research and Practice, (Georgetown University Press 1990). Professor Flynn also had chapters in four refereed volumes accepted for publication: "Linguistic Theory and Foreign Language Learning and Teaching," K. de Bot, C. Kramsch, R. Ginsberg (eds.) in Issues in Foreign

Language Learning and Teaching (J. Benjamin Press, 1991); "Age Dependent Effects in Language Acquisition: An Evaluation of 'Critical Period' Hypothesis," with S. Manual, L. Eubank (ed.) in UG and L2 Acquisition (J. Benjamin Press, 1991); "Interactions between L2 Learning and Linguistic Theory," F. Eckman (ed.) in Second Language Learning and Language Pathology and "Parameter-Setting in SLA: Within a UG Framework," C. Ferguson and T. Huebner (eds.) in Theoretical Approaches to Second Language Acquisition (1991).

Foreign Languages and Literatures faculty and lecturers are professionally engaged in widely ranging fields and many have given lectures nationally: at the Linguistic Society of America (Prof. Harris), the MLA (Prof. Garrels), the American Association for the Advancement of Science (Prof. Flynn), the University of Chicago and Brown University (Sr. Lecturer Furstenberg), the Association for Asian Studies (Lecturer Yoshie Kawamura), and internationally: the World Congress of Slavic and East European Studies, and the International Association of Teachers of Russian Language and Literature (Prof. Chvany), the International Association for Applied Linguistics and the University of Seoul (Prof. Flynn), the U. of Caracas (Prof. Garrels), and the U. of Berlin (Sr. Lecturer Furstenberg). Other professional activities include the following: Janet Murray serves as a panelist/reviewer for the National Endowment for the Humanities, Prof. Flynn was made Associate Editor of Linguistic Inquiry, and Sr. Lecturer Morgenstern serves on the Advisory Board of WGBH Destinos. Director of the Language Learning and Resource Center, Ruth Trometer, has served as President of the International Association of Learning Laboratories (IALL) for the past two years. Professor Resnick was recognized for her outstanding teaching abilities with the Baker Award for Excellence in Teaching.

Within the Institute, faculty in FL&L have served on Committees such as: the Consortium Committee, the Committee on Nominations, the Equal Opportunity Committee, the Sloan School Committee on Master's in European Studies, the Committee on the Writing Requirement and the MIT Committee on Academic Computing, among others.

While the number of majors (ten) has increased slightly and the number of concentrators (202) has remained constant, the number of minors (61) has increased dramatically. This year, Spanish had the largest enrollments (403), followed by French (332), German (320), English as a Second Language (269), Japanese (244), World Literature in Translation (232), and Russian (143). FLL subjects continue to receive some of the highest ratings in the Student Course Evaluation Guide.

Professor Isabelle de Courtivron assumed the position of Head as of July 1, 1990. In this important time of transition, one of FL&L's main goals has been to make new full-time appointments and to decrease the number of part-time and visiting faculty. Professor Miyagawa, formerly of Ohio State University, was appointed at the rank of Full Professor. Professor Turk was promoted to the rank of Full Professor effective July 1, 1990. Other appointments include: Visiting Assistant Professor of Chinese, Yih-jian Tai, and Shoggy Waryn, full-time Lecturer in French. Next year, our goal is to begin to rebuild the ranks of junior faculty. FL&L continues its leadership role in the hiring of women, who comprise 60 percent of the Section's faculty, and affirmed its commitment to minority hiring at every level by promoting Administrative Assistant Zachary Knight to Administrative Officer.

ISABELLE DE COURTIVRON

History Section

FACULTY APPOINTMENTS

Historians kept very busy this year replacing retiring faculty and filling new appointments. A search to replace Professor Richard M. Douglas with a Medieval and Early Modern European historian resulted in a successful offer to Anne McCants, a recent Berkeley Ph.D. whose research interests revolved around the social and economic operations of a 17th-century Dutch orphanage. Professor Harald Reiche's position in Ancient History found a successor in Jon E. Lendon, an outstanding Roman and Greek historian from Yale, whose dissertation examines the social basis of Roman imperial rule. The 20th-century junior American history position was finally filled with an offer to Christian Appy, from Harvard University's History and Literature program, who has studied the experience of American soldiers in the Vietnam War. Robin Kilson, who taught at MIT for one year as an Instructor before leaving for Bryn Mawr, returned as an Assistant Professor in European history and African studies. We were delighted to welcome her back. We were pleased that all our first-choice candidates accepted our offers. With the arrival of so many excellent junior faculty we look forward to new growth in the department's teaching and research activities. In addition, a joint appointment to Associate Professor Harriet Ritvo of the Writing Program strengthened our links with other parts of the Humanities, and the arrival of our two senior appointments, John Dower in Japanese history and Alexander Keyssar in American history will add to distinction in these fields. Professor Dower will hold the Henry R. Luce Chair in International Cooperation and Global Stability and was elected in 1991 along with Professor Merritt Roe Smith as a Fellow of the American Academy of Arts and Sciences. The addition of seven new people in one year is an unprecedented experience which should galvanize new directions for the entire faculty.

Increasing the faculty and creating a curriculum to cover most of the globe have been steps in our ongoing quest for diversity and multi-cultural awareness. These new appointments decisively shifted the composition of the faculty away from its traditional white male dominance. Now five of the tenured and tenure-track faculty will be women among whom one is an African-American (seven including visiting appointments), (35 percent). After arduous effort and anxious debate, we have made welcome progress toward Affirmative Action objectives.

Instructor Elizabeth Wood, who was appointed as an Instructor for 1990-91, has received her Ph.D. from the University of Michigan this spring and will hold the title of Assistant Professor effective July 1, 1991.

Professor Philip Khoury, who served as Acting Dean of the School of Humanities and Social Science this year, accepted the appointment as Dean of the School, beginning July 1, 1991.

PUBLICATIONS AND RESEARCH

Assistant Professor Douglas Forsyth signed a contract with Cambridge University Press for his manuscript on *"Monetary and Financial Policy and the Crisis of Liberal Italy"*, and published an article on *"The Rise and Fall of German-Inspired Mixed Banking in Italy, 1894-1936"*. Acting Dean Khoury co-edited *Tribes and State Formation in the Middle East* (University of California Press), and published *"The Reagan Administration and the Middle East"* and *"The Urban Notables Paradigm Revisited."* Associate Professor David Ralston delivered a paper on *"The Transfer of Military Science and Technology between Europe and Asia, 1498-1780"* at The First Conference on the Transfer of Science and Technology between Europe and Asia since Vasco da Gama. Professor Ritvo co-edited *The Macropolitics of Nineteenth-Century*

Literature: Nationalism, Imperialism, Exoticism (University of Pennsylvania Press). Professor Ritvo also won the prestigious Whiting Writers' Award for 1990. Visiting Assistant Professor Sherifa Zuhur's manuscript, *Women Revealing Women: Egyptian Women and New Muslim Self-Image*, was accepted for publication by SUNY Press.

OTHER ACTIVITIES

Professor Bruce Mazlish continued to promote interdisciplinary cooperation by co-directing the History and Literature Workshop. Middle Eastern topics came to the fore this year. Acting Dean Khoury continued to chair the Emile Bustani Seminar Lecture Series. Visiting Professor Zuhur organized a study group and concerts on music of the Middle East, sponsored by the Office of the Arts and screened films on women in the Middle East at MIT. She and Acting Dean Khoury participated in MIT Faculty Teach-Ins on the Gulf War.

Committees: Professors Mazlish, Smith, Loren Graham, and Associate Professor Peter Perdue participated actively in the ongoing negotiations for the establishment of the Dibner Institute for the History of Science, and in the search for a Director of the Institute chaired by Acting Dean Khoury. Professors Mazlish, Ritvo, and Perdue served in planning activities of the Cultural Studies project. Professor Perdue chaired a new committee on Academic Computing within the School and will serve on the new Institute Committee on Academic Computing. Visiting Assistant Professor June Namias continued to serve ably as the Undergraduate Research Opportunities Program Coordinator and also was a member of the Women's Study Committee. Professor William Watson (also Housemaster, Baker House) became a recent member of the Committee on Discipline. Professors Pauline Maier and Forsyth contributed their time to the HASS-D Historical Studies Subcommittee as chair and member respectively. Associate Professor Arthur Kaledin served on the MIT Faculty Committee on the Library System and on the ISP Committee.

The History Workshop this year invited four distinguished scholars to lecture on the theme of History and the Global Environment. A grant of \$25,000 from Dr. Kenan Sahin, Chairman and President of Kenan Systems, will enable us to organize activities like the aforementioned lecture series that will bring together the faculty around topics of common intellectual interest.

Curriculum: Historians increased their activity in graduate education. Visiting Assistant Professor Ronald Edsforth helped graduate students prepare oral exams in the joint Ph.D. program in History and Social Study of Science and Technology, and Professor Mazlish taught the graduate seminar in historiography. Professor Forsyth advised graduate students doing theses in Political Science, and Professor Robert Fogelson served on the Ph.D. committee of the Urban Studies department. History Faculty also introduced new graduate subjects on "The State and Economy in Europe" (Professor Forsyth), "The Culture of Capitalism" (Professor Mazlish and Associate Professor Rosalind Williams), and "War, Society, and Problems of Reconstruction in Lebanon" (Acting Dean Khoury).

Historians added six new subjects to the undergraduate curriculum, including "The Age of Reason" (Professor Ralston), "American Cultures: Images, Places, Texts" (Professor Kaledin), "Britain in the 18th and 19th Centuries" (Professor Ritvo), and "Unveiling Eve: Women's History in the Middle East" (Professor Zuhur).

Professor Forsyth directed the History Faculty's most ambitious collective curricular project, a two subject sequence on "The Last Hundred Years: Topics in World History" which emphasized linkages between major events and processes around the globe during the twentieth century and the effects of world-historical change on

the relationship between human beings and the natural environment. The close collaboration and teaching efforts of both Professors Forsyth and Douglas drew large enrollments and good student response for such a pioneering, demanding topic.

Participating in our History program were 12 majors, 21 minors, and 128 concentrators. Student enrollment in history courses during the academic year totalled 906. Undergraduates wrote theses on topics including "The U.S. Supreme Court of 1944 and Korematsu versus United States": R. Choi, "War Perceived in American Popular Culture": A. Duffin, and "Copyright Protection of Computer Software": S. Garren.

Colleagues and friends of retiring Professors Reiche and Douglas joined in celebrations of their many years of devoted service to the Institute.

Peter C. Perdue

Literature Section

The Literature Faculty at MIT has continued to be a highly productive scholarly community whose contributions to film and media study and various forms of cultural study, as well as to literary scholarship, are widely respected. This year was marked by the arrival of two new Assistant Professors, Mary Fuller and Louis Galdieri, and Visiting Professor Kai Hong from Seoul Institute of the Arts, by the introduction of several innovative subjects in the HASS-D tier of the curriculum, and by the inception of the Cultural Studies Project at MIT, under the direction of Professor David Thorburn.

Following a banner year in which members of the faculty published six books, research and publication continued at a brisk pace. Professor Cynthia Wolff continued work on "The Woman Who Made War: Harriet Beecher Stowe," under contract at Knopf, and published a comprehensive edition of Edith Wharton's *Touchstone* and an edition of Edith Wharton's *Novellas and Other Writings* in the Library of America series. Professor Alvin Kibel completed several essays on literary canons and taxonomies in literature and biology. Professor Irene Tayler continues research on "Veiled Woman: the Evolution of an Image." Professor Peter Donaldson published a study of Kenneth Branagh's film adaptation of *Henry V* in *Shakespeare Quarterly*, and completed a study of several film versions of *A Midsummer Night's Dream*. Professor Thorburn completed a historical overview of the field of television studies for the *Yale Journal of Criticism* and contributed a chapter to a volume on *The Television Western*. Professor David Halperin continued his research on gender and erotic theory in classical Greece with an article in *Differences* and further work on "The Metaphysics of Desire: Plato and the Origins of Erotic Theory in the West" under contract at Yale University Press. Professor Stephen Tapscott continued to produce critical work on other poets, contributing an essay on Stephen Dobyns to the *New Boston Review*. One of Professor Tapscott's own poems appeared this year in *Ploughshares*, and six of his poems were anthologized, with an autobiographical introduction, in *Catholic Poets of America* (Notre Dame: University of Notre Dame Press, 1991). Professor John Hildebidle published poems, essays, critical studies and short fiction in *Twentieth Century Literature*, *Yankee* and *Bostonia*, and contributed to a volume on *Education for Judgment*, published by the Harvard Business School. Professor Ruth Perry co-edited a volume on *Social Control and the Arts* with Susan Suleiman and Alice Jardine, contributed essays to *Eighteenth Century Studies* and *Signs*, and continues work on her study of the family and the novel in eighteenth-century culture. Professor Theoharis C. Theoharis continued work on his study of Aristotelian and Nietzschean theories of dramatic action in the works of Ibsen, Beckett and O'Neill. Professor Rita Goldberg is writing a book on compassion and the rise of the victim in eighteenth century literature. Professor Henry Jenkins' book on film comedy and its vaudeville roots has been accepted by Columbia University Press. He continues work on two books on audience reception of television narrative under contract at Routledge, has published an essay in *The Velvet Light Trap* (also translated into Italian and published in a collection of essays on RKO and Monogram film comedies of the 30's and 40's), and has contributed a chapter to a volume on mass culture published by the British Film Institute. Professor Fuller has published an article in *Representations* and is revising her dissertation on Renaissance accounts of America. Professor Galdieri is revising his dissertation on Thomas More and Renaissance historiography for publication.

Members of the faculty have also presented their work at a number of conferences including meetings of the Shakespeare Association of America, Northeast Modern Language Association, Ohio Shakespeare Conference, American Society for Eighteenth Century Studies, Modern Language Association, California Classical Association, American Philological Society, Citadel Conference on Medieval and Renaissance Literature, International Association for Philosophy and Literature, Jane Austen Society of America, The Michigan Conference on Women's Studies, The Society for Cinema Studies, and the International Television Studies Conference, and have delivered public lectures and presentations at Virginia Polytechnic Institute, Simmons College, University of Minnesota, University of Pennsylvania, Duke University, University of Chicago, University of Michigan, Ann Arbor, University of California, Los Angeles, University of California, Santa Cruz, University of California, San Diego, University of Wisconsin, Madison, Pomona College, Dominican College (San Francisco), University of Oregon, Stanford University, University of California, Riverside, Hong Kong University, Harvard University, University of Illinois, Tufts University, Charles University (Prague), University of Hamburg, Copenhagen University, University of Otago (N.Z.), and University of Auckland.

This year, Professor Halperin was appointed Visiting Professor at the University of California, Santa Cruz (Spring Term), and Professor Wolff spoke as Distinguished Lecturer at Emory University (Women's Studies) and at Hamilton College. Professor Halperin was appointed editor of "Ideologies of Desire," a monograph series published by Oxford University Press. Professor Tapscott was awarded a Fellowship at the Virginia Center for the Creative Arts, and was also co-recipient (with Glorianna Davenport of the Media Lab), of the Gyorgy Kepes Prize for the Arts. Professor Tapscott was also honored by an invitation to compose a "Poem of Welcome" on the occasion of the inauguration of Dr. Charles M. Vest as President of MIT.

Professor Thorburn was appointed Director of the Cultural Studies Project at MIT. This project, which is meant to serve as a focus for many interdisciplinary activities in the humanities, and draws on faculty from Literature, Writing, Foreign Languages and Literatures, History, Music and Anthropology, began its first year with an international conference on "Epidemics: Perspectives in Cultural Studies", held at MIT in October, and hosted a conference on "Melodrama Across Cultures" in May. Faculty in Literature, including Professors Halperin, Wolff, Perry, and Donaldson were also active in the Cultural Studies Project conferences. Professor Goldberg continues, with Professor Bruce Mazlish of History, as codirector of the History-Literature workshops.

Professor Goldberg was promoted to Associate Professor of Literature, beginning July 1, 1990. Three new faculty members arrived this year: Professor Louis Galdieri, who holds a Ph.D. from University of California, Berkeley, was appointed Assistant Professor of Literature beginning July 1, 1991. Professor Galdieri works in Medieval and Early Modern Literature, and specializes in Renaissance humanism, rhetoric and historiography. Professor Mary Fuller received a Ph.D. from the Johns Hopkins University, and specializes in Renaissance Literature. Professor Kai Hong, who holds a Ph.D. in Philosophy from MIT and is Professor of Aesthetics at the Seoul Institute for the Arts, was appointed Visiting Professor of Literature beginning in January, 1991. Professor Hong will concurrently hold the first Ye-Eum Foundation Fellowship, a multi-year grant similar in purpose to the MacArthur Prize Fellowships in the United States. The Literature Faculty is pursuing the goals of cultural diversity, and is continuing its efforts to attract minority faculty. This year we offered an Assistant Professorship to a minority scholar of Afro-American Literature who was exceptionally promising, and who, unfortunately, declined our offer. Our efforts continue and will be renewed with vigor in 1991-2. This year, Monica Kearney, who had served as Administrative Officer, resigned to become Administrative Officer in the Economics Department, and Eve Diana, formerly Administrative Secretary in the Chemistry Department, joined the Section as Administrative Officer in August, 1990.

During the past year, 1272 students enrolled in Literature subjects, 28 were registered as Literature majors, 41 as minors, and 259 as concentrators in Literature for the HASS requirement. The Literature Faculty continues to participate actively in the curricular reforms of the School: this year, several innovative and collaborative HASS-D subjects were offered for the first time, including *The End of Nature* taught by Professor Kibel and Professor James Paradis (Writing) and *Forms of Western Narrative*, taught by Professor Thorburn. Professor Wolff's innovative HASS-D subject, *Decoding the Narratives of American Culture* will be offered for the first time in 1991-2. With two newly appointed Assistant Professors in Renaissance Literature, an extensive review of the undergraduate offering in Medieval and Renaissance Literature has been undertaken by Professors Donaldson, Galdieri and Fuller, with support from the Dean's Office. Professor Donaldson has also begun to collaborate with Dr. Janet Murray of the Athena Language Learning Project on an enterprise intended to utilize computer-assisted interactive videodisc technology in the study of Shakespeare at MIT. The Shakespeare Hypermedia Project will link electronic text and multiple performance versions of Shakespeare plays, bringing together some of the innovations in interactive videodisc pedagogy made under Dr. Murray's leadership in Project Athena, and Professor Donaldson's work in using Shakespeare on film in the classroom.

The Literature Faculty continues, in its research, teaching, and participation in the life of the Institute, to pursue the goal of scholarly excellence, and to grapple, energetically, with questions of diversity and tradition, in an effort to define -- and continually redefine -- the role of humanistic study in a technological society.

Music and Theater Arts Section

Music and Theater Arts has seen major developments in its administrative structure during 1990-91, as well as continued growth in educational and creative activity.

During the spring semester, the faculty voted to depart from its policy of a yearly rotating chair and retain Professor Alan Brody as Section Head through 1993 when it will consider his renewal for another two-year term. This opened the way for Music and Theater Arts to have its own Visiting Committee which will meet in the fall of 1992.

This year saw 1269 students registered in music classes and 238 in theater arts, reflecting an overall increase of 124 in the section's enrollment. The 1991 graduating class included 11 majors, 21 minors, and 95 concentrators in music, 2 minors and 7 concentrators in theater arts.

Theater Arts took a major step toward greater diversity with guest artist, Decima Francis, initiating a Theater Workshop for Minority Students. Melanie Lazar, '92, won first prize in the Playwriting division of the Writing Prizes with her play, Love Is Blind, which was developed in Ms. Francis' Workshop. Yu Hasegawa, '91, took second place with two one-act plays which came out of the Playwriting course. Playwrights in Performance produced one of Ms. Hasegawa's plays along with pieces by Carlos Rabell, '93, a Puerto Rican student, Omar Green, '92, an African-American student, and Glen Weinstein, '92, whose play, SJM, dealt specifically with Jewish-American themes.

Major musical events during 1990-91 included concerts by the world-renowned Emerson String Quartet, with Professor Marcus Thompson assisting on viola, and the Lydian String Quartet performing compositions by Professor John Harbison and Associate Professor Peter Child. Professors Harbison and Child were also commissioned, along with Assistant Professor Evan Ziporyn and Senior Lecturer Edward Cohen, to write fanfares for the inauguration ceremonies of President Charles Vest.

Media attention focused on a double bill of recent music and dance works performed by artists-in-residence Karol Bennett and John MacDonald and Beth Soll and Company. The program featured the premiere of Senior Lecturer Beth Soll's Sanddance and Outset, song cycles by Professors Child and Harbison, and a piano composition by Professor Ziporyn. The Opera Laboratory Theater of Boston, company-in-residence with Theater Arts, premiered an acclaimed production of The Rake's Progress. Dance was further represented with the appearance of Gregory Hines as 1991 Abramowitz Lecturer.

Our music ensembles figured prominently among the festivities surrounding the Inauguration. On Inaugural Eve President and Mrs. Vest and their guests heard "Showcase" performances by the Symphony, Concert Band, Chamber Chorus and Festival Jazz Ensemble. The next two evenings featured the 160 voices of the MIT Concert Choir and Chamber Chorus in Mendelssohn's Elijah, and the MIT Symphony in a concert of works by Brahms, Copland and Mozart. In all, the MIT community heard 109 section-sponsored concerts during the academic year.

This was also a year of great student accomplishment. The Festival Jazz Ensemble, under the direction of Lecturer Jamshied Sharifi, '83, captured the award for Outstanding Performance at the Collegiate Jazz Festival at Notre Dame, while Ensemble member Susan Ward won an individual award for Best Tenor Sax Performance. The Ensemble also received the Wiesner Award. Theater Arts student, Julie Schmittdeil, '91, won the Sudler Prize, and David Oh, '91, the Edgerton Award for Excellence in Music. The Ragnar Naess Awards in Music went to Dawn Watkins, '92, and Erika Anderson, '91. Glen Daniel Weinstein, '92, won the Theater Arts Writing Award and Jonathon Rockman, '91, the Edward S. Darna Theater Award.

Faculty and staff continue their professional activities and achievements at home and abroad. Professor Thompson recorded with the Boston Chamber Music Society, the Radio Orchestra of Ljubjana and the Amsterdam Chamber Music Society. His concert appearances took him to Los Angeles, Chicago, Pittsburgh, Berkeley, Amsterdam, Okinawa and Tokyo.

Professor Harbison, on leave, served as Creative Chair of the Saint Paul Chamber Orchestra, conducting two world premieres and numerous other twentieth century pieces. He also conducted the Los Angeles Chamber Orchestra, the Milwaukee Symphony Chorus, and Voices of Change in Dallas. His Symphony Number 3 had its world premiere with the Baltimore Symphony, his Two Emmanuel Motets with the Emmanuel Choir. Honors included his selection as Mary Biddle Lecturer at Duke University and his appointment to the Board of Trustees of the American Academy in Rome. He also served as Resident Composer for the First American Music Week Celebration in Berlin and at the Ojai Festival.

Professor Child's Ensemblance was recorded for the BBC, London, and subsequently performed by Collage New Music Ensemble at Symphony Hall. Professor Ziporyn performed his own work, as well as other contemporary pieces, with the Relache Ensemble in Philadelphia, the Michigan New Music Ensemble, New Music America in Montreal, the Avant Garde Festival at Tallinn, Estonia, and Merkin Hall in New York City. He also sang the role of Vincent Van Gogh in Michael Gordon's Van Gogh Video Opera in New York City.

Alan Brody's play, The Company of Angels, won the 1990 Eisner Award from the Streisand Center for Jewish Culture in Los Angeles. His new play, Greytop in Love, had its first public performance at the Missouri Repertory Theater in Kansas City. Professor Brody was also very active on several Institute Committees, including the Provost's Search Committee for the position of Dean of the School of Humanities and Social Science and the K-12 Committee. Senior Lecturer Soll taught and performed in Budapest during the summer of 1990. Her Company was invited to perform at the Museum of Modern Art in Los Angeles.

In the field of Music scholarship, Associate Professor Lowell Lindgren, under an NEH Fellowship, published a facsimile edition of Camilla by Giovanni Bononcini and Musicians and Librettists in the Correspondence of Giovanni Giacomo Zamboni. Professor Child's article, "Structural Unities in a Work of Bartok: 'Boating'" appeared in Mikrokosmos; Professor David Epstein published articles in Brahms Studies, Romantic Music, Quo Vadis Musica, and Psychoanalysis and Music. Professor Ellen Harris' "Integrity and Improvisation in the music of Handel," appeared in the Journal of Musicology; Assistant Professor Martin Marks delivered papers on film music at the American Musicological Society in Oakland, the Cinema Studies Conference in Los Angeles and at the UCLA Department of Musicology. He also gave several lecture/performances at Harvard University.

President Emeritus Jerome Wiesner led many members of the MIT Community in sharing remembrances of the Professor Emeritus Klaus Liepmann at a moving Memorial Service held in November. Professor Liepmann, who was known as the Father of Music at MIT, had passed away in July.

The end of this academic year also marked the retirement of former Section Head, Professor Stephen Erdely, and beloved Lecturer, Claudia von Canon. The Music and Theater Arts Section wished them well at a special concert/reception featuring cameo performances by many of the music faculty and staff.

Alan Brody

Writing Program

The Writing Program performs a vital teaching service at the Institute. The Program's curriculum maintains a depth and balance appropriate for the diverse student population. The current undergraduate subjects in expository writing, creative writing, and science and technical writing draw a steady enrollment of students at all levels, advanced and beginning alike. Many subjects satisfy either Phase One or Phase Two of the Institute Writing Requirement. The cooperative writing subjects for both undergraduates and graduate students, within the various engineering departments, continue to hold their enrollments. Undergraduate cooperative subjects now exist within several departments in the School of Science. The summer session course 21.10s Communicating Technical Information was again popular with many students from industries throughout the world. The Writing Program sponsored, under the direction of Senior Lecturer Edward Barrett, the first annual conference on "The Social Creation of Knowledge: Multimedia and Information Technologies in the University," a one-day international conference with workshops and presentations on the use of multimedia and information technology to support collaborative research, learning, and instruction.

In addition to offering an academic curriculum for the student body, the Program brings to the larger MIT community distinguished writers and poets who share their ideas about their work and craft of writing. Peter Gizzi and Connell McGrath read from their forthcoming collections of poems. William Corbett, one of Boston's most renowned poets, read from recent and past works, as did Pierre Martory and Rosanne Wasserman. Lastly, the poetry reading series featured readings by Michael Gizzi and Rosmarie Waldrop. In addition, the Writing Program sponsored two lectures during the academic year. The first was presented by Professor Alan Lightman and entitled "The Lives and Worlds of Modern Cosmologists." The second, entitled "The Dilemma of Scientific Subjectivity," was delivered by Evelyn Fox Keller.

Professor Lightman published a new book entitled *Origins: The Lives and Worlds of Modern Cosmologists*, (Harvard University Press, 1990). His book won the Association of American Publishers Award for the most outstanding book in physical science for 1990. Professor James Paradis edited a volume of essays entitled *Textual Dynamics of the Professions: Historical and Contemporary Studies of Writing in the Professional Communities* (University of Wisconsin Press, 1991). Associate Professor Harriet Ritvo was one of ten American writers to receive a Whiting Writers' Award given in recognition of outstanding literary accomplishment. She also edited *Macropolitics of Nineteenth-Century Literature: Nationalism, Exoticism, Imperialism* (University of Pennsylvania Press, 1991). She assumed a joint appointment in the History section, effective July 1, 1991. Assistant Professor Thomas Simmons published his new book entitled *The Unseen Shore: Memories of a Christian Science Childhood* (Beacon Press, 1991). Visiting Writer Arturo Vivante published a book of short stories entitled *The Tales of Arturo Vivante* (Sheep Meadow Press, 1990) and Visiting Writer Pamela Alexander published her book of poems entitled *Commonwealth of Wings: An Ornithological Biography Based on the Life of John James Audubon* (Wesleyan University Press, 1991). Adjunct Professor Joe Haldeman published *The Hemingway Hoax* (Avon Books, 1990) and Part-time Lecturer Eugene Mallove published *Fire from Ice: Searching for the Truth Behind the Cold Fusion Furor* (John Wiley & Sons, Inc., 1991). Professor Kenneth Manning presented the George Sarton Memorial Lecture at the 1991 annual meeting of the American Association for the Advancement of Science. He continues his project on "Blacks in American Medicine, 1860-1980." Professor Elżbieta Chodakowska continues her biography of Hannah Arendt. Associate Professor Rosalind Williams continues her work on the cultural history of technology.

Professor Manning stepped down as Head of the Writing Program and was replaced by Professor Lightman, effective July 1, 1991.

Kenneth R. Manning

Department of Linguistics and Philosophy

INTRODUCTION

Work in the Department of Linguistics & Philosophy went ahead at its usual, serious level during the year. There were no new faculty appointments this year though a search for a senior philosopher remains under way. The Department also continues to be unusually successful in placing the graduates of its two Ph.D. programs.

RESEARCH: LINGUISTICS

Recent work suggests that syntactic variation among languages is determined by "functional" (nonsubstantive) elements of the lexicon, that the relations among elements that enter into explanation of form and meaning are restricted to a few structural types, and that well-formed structures are constrained by general conditions of economy of computation and representation. Current research - within this framework - seeks to provide a unified theory of inflectional systems that incorporates basic principles of universal grammar and predicts many of the properties of language as these systems are determined within a limited range. Also within this general framework, research on the syntax and semantics of the ergative construction continues, aided now by the receipt of an NSF research grant for work on these topics.

Research in the theory of morphology and phonology ranges from work on quite specific topics (e.g. enclitic accent in Latin, Macedonian, Italian, Polish; syllabification rules in Spanish and Catalan) to the very general (e.g. on the Free Element Condition and on the logical foundations of phonetics).

RESEARCH: PHILOSOPHY

There are a number of topics being pursued in the current research in philosophy: consciousness; logical omniscience; the nature of happiness; natural kinds; interrogatives; Russell's and Frege's philosophies of mathematics; the Frege-Russell conception of logic; scientific conceptions of language and their philosophical import; and scientific development and lexical change.

PUBLICATIONS

As in the past, the faculty of both sides of the department published a large number of chapters in books and journal articles and reviews. In addition, Professor Judith Thomson's The Realm of Rights was published by Harvard University Press.

HONORS AND AWARDS

Professor Richard Cartwright received the Distinguished [Alumni] Achievement Award from Brown University; Professor Noam Chomsky was the recipient of the Institute's James R. Killian Faculty Achievement Award and was honored as well with the publication of The Chomskyan Turn (A. Kasher, ed., Oxford: Blackwell, 1991) - the proceedings of a recent conference held on or near the occasion of his sixtieth birthday; Professor Morris Halle has been awarded the 1991 scientific prize of the Union d'Assurances de Paris; Professor Thomas Kuhn received an honorary degree (Doctor of Letters) from Columbia University; and Professor Thomson was elected Vice President of the American Philosophical Association.

In February, the Department of Philosophy of Brock University (Canada) held a three-day symposium on Professor Irving Singer's trilogy The Nature of Love.

LEAVES OF ABSENCE

Assistant Professor David Brink spent the year as a Resident Fellow at the Center for Advanced Study in the Behavioral Sciences (Stanford), and Assistant Professor Michael Hardimon was at Harvard University on a Ford Foundation Post-doctoral Fellowship for Minorities.

PERSONNEL

We report, with pleasure, Professor Brink's promotion to Associate Professor, effective 1 July 1991, and with regret, Professor Kuhn's retirement from the department after twelve years at the Institute - although we expect the latter, in his retirement, to continue to contribute importantly to the intellectual life of the department.

The department's major affirmative-action goal, to increase the representation of women on the faculty to at least three from the present two, remains to be met - there having been no additions to the faculty during the present academic year. The more distant goal, that of increasing the number of faculty from underrepresented minority groups from its current and dismal level of one, continues to elude us.

The department concluded the year with a very successful MIT faculty mini-course on linguistics. This well-attended, week-long (17-21 June) course was organized and led by Alec Marantz with the participation of these members of the Linguistics Faculty as well: Professors Noam Chomsky, Morris Halle, James Harris, James Higginbotham, Jay Keyser, Wayne O'Neil, and David Pesetsky.

WAYNE O'NEIL

Department of Political Science

The challenges of contributing both to fundamental social science understanding and to analysis of critical issues of our times continue to be at the heart of teaching and research in the Department of Political Science. A few of these issues deserve special mention, since they had unusual impact on work in the department this year. The war in the Middle East found faculty members writing and teaching about the events as they unfolded. Professor Barry R. Posen's papers on military strategies in the Gulf received wide circulation and comment. An IAP series on the Gulf organized by Professor Harvey M. Sapolsky drew large audiences to listen to Political Science faculty analyze various aspects of Middle East tensions. Research activities on postwar reconstruction in the region involved faculty in work on Kuwait, Lebanon, and Afghanistan. This summer Professor Myron Weiner heads a team that will work in Pakistan on the Afghan border interviewing Afghans in order to propose new initiatives for relief and rebuilding. The continuing international tensions generated by technological competition and trade among advanced industrial countries is a focus for another group of faculty. Professor Richard J. Samuels' work on Japanese technology addresses these issues, as does the MIT-Japan Program he heads, which enrolls hundreds of undergraduates for study of Japanese culture, politics and language before sending them to internships in Japanese companies and laboratories. Professor Charles F. Sabel's research on evolving industrial structures considers these issues as part of a revision of conventional theories of economic development; at the same time, Professor Sabel has been working with employers, unions, and state government in Pennsylvania to develop new state-level industrial programs. The problems of race and poverty in the United States are central to the efforts of some of the faculty. Here there have been new teaching activities this year as well as research. In the fall, Professor Michael Lipsky organized an undergraduate seminar "The Struggle for Equality: Issues in African-American Politics;" in the spring he and others from the department organized "Politics, Cambridge, and the MIT Student," an internship subject that placed 18 students in Cambridge agencies and organized classroom instruction around their experiences. The issues of global environment are a major focus in the department. Professor Nazli Choucri's interdisciplinary faculty seminar continues strong after three years; new subjects are planned; and a stream of articles on the topic shows research in progress. Finally, after a period of relative inactivity in the area, telecommunications research is again generating interest in the department. In October 1990, a one-day symposium in memory of the late Professor Ithiel de Sola Pool presented new issues in telecommunications policy.

The department continues a major recruitment effort for new faculty, seeking to fill vacant slots in American politics and methodology, to fill a new position in comparative European politics, and to identify outstanding political scientists regardless of field. With respect to this last point, we are especially concerned to find more minority faculty for the department. The underrepresentation of minorities and of women in our faculty is a significant loss for our students, to whom we wish to present both a range of perspectives and a set of

models for their own aspirations and careers. In order to address this issue, we have widened our search efforts by contacting all faculty members of the American Political Science Association who are identified as Black or Hispanic as well as widely advertising our positions. We have looked to the professions for underrepresented minority members with distinguished reputations, and have appointed Ms. Margaret Burnham, a Black attorney and former Boston Municipal Court judge, as a Lecturer. We have used opportunities for visiting appointments, for example, hiring Professor James Jennings, a Black Puerto Rican political scientist, to replace Professor Lipsky during his leave. We ran a competition for a postdoctoral fellow, and appointed Dr. Kenneth Williams, a Black political scientist from Michigan State University, for 1990-91. We plan to continue these efforts as well as our program for increasing the recruitment of graduate students from underrepresented minority groups. This involves arranging for our faculty to meet and discuss education at MIT with minority students on other university campuses.

Within the department last year, three faculty members were promoted, effective July 1, 1991. Assistant Professors Jonathan Fox and Ellen M. Immergut were promoted to Associate Professors. Professor Immergut was named to the Ford International Career Development Chair. Associate Professor Posen was promoted to Full Professor. After 34 years at MIT, Professor Lincoln P. Bloomfield retired on June 30. He was honored with a day-long colloquium, "The Unconventional University," in the course of which Professor Harlan Cleveland from the University of Minnesota and President of the World Academy of Art and Science; the Honorable Elliot Richardson, former Secretary of Defense and Attorney General and former Chairman, United Nations Association; and Sir John Thomson, Principal Director, 21st Century Trust and former Ambassador to NATO and the United Nations, spoke. The colloquium was featured as an inaugural event. At the dinner that closed the day's events, President Charles Vest read a letter to Professor Bloomfield from President George Bush, praising him for contributions to public service.

The department's teaching program continues to evolve, with new subjects offered by regular faculty and by visitors. The new undergraduate subjects that focus on race and on community politics (described above) will continue to be offered. Professor Eugene B. Skolnikoff will give a new freshman seminar, "How Technology-Related Policies are Made." He will also be teaching a new subject on comparative science policy. Professor Choucri will offer a new graduate subject, "Politics of Global Change." Professor Sabel with Visiting Professor Horst Kern taught a graduate workshop on reorganization of the welfare state. Professors Sapolsky and Posen presented a new subject on innovation in military organizations. Work by students in the Defense and Arms Control Studies Program is presented in a new publication, "Breakthroughs," edited by Professor Sapolsky. Associate Professor Charles Stewart III is working with faculty from the Economics Department and from Harvard to develop a "Research Training Group in Positive Political Economy." Visiting Professor Marcelo Cavarozzi won the Graduate Student Association Award as best teacher in the School of Humanities and Social Science.

The scholarly publications of the faculty continue in a strong stream. A list of articles and monographs would be too long to reproduce here, and so we note only recent books and those that will appear before the end of 1991. We recognize, however, that this does little justice to those faculty members whose normal mode of scholarly communication is articles. Professor Fox's edited volume, The Challenge of Rural Democratisation: Perspectives from Latin America and the Philippines (Frank Cass), appeared this year. Professor Sapolsky published Science and the Navy (Princeton University Press) and, with R. Crane, E. Noam, and R. Neuman, an edited volume, The Telecommunications Revolution (Routledge). Professor Posen's Inadvertent Escalation: Conventional War and Nuclear Risks (Cornell University Press) will appear this fall as will Professor Immergut's The Political Construction of Interests: National Health Insurance Policies in Sweden, France, and Switzerland (Cambridge University Press), and Associate Professor Kenneth A. Oye's Economic Discrimination and Political Exchange: World Political Economy in the 1930s and 1980s (Princeton University Press). With Robert Lieber and Donald Rothchild, Professor Oye has edited Eagle in a New World: American Grand Strategy in the Post-Cold War Era (HarperCollins). A new edition of Professor Lucian W. Pye's Spirit of Chinese Politics (Harvard University Press) is forthcoming. Professor Stephen W. Van Evera, together with S.L. Jones and S.E. Miller, edited Nuclear Diplomacy and Crisis Management: An International Security Reader (MIT Press).

Faculty received various honors and grants this year. Professor Posen was awarded the Levitan Prize in the Humanities for his project on nationalism and war. Professor Willard R. Johnson received a Distinguished Scholarship Award from the University of Massachusetts at Boston. Professor Sapolsky was elected a fellow in the National Academy of Social Insurance. Professor Pye was chosen to present the Edmund James Lecture at the University of Illinois. Associate Professor Richard M. Valelly received a fellowship from the W.E.B. DuBois Institute for Afro-American Research. The Center for European Studies awarded Professor Sabel funds for research on East Germany. Professor Stewart received an NSF grant for work on the committee system in the House of Representatives. Fulbright grants were given to Professor Johnson, for participation in a summer program in Indonesia, and to Professor Samuels, for research in Japan on civilian and military technologies. Professor Fox received grants from the Heinz Foundation and the Inter-American Foundation for research on citizen participation in rural development. Professor Weiner has received a Sloan Foundation grant for a conference on the impact of immigration on the security and internal stability of states, to be held this fall at the Center for International Studies. Professor Stephen M. Meyer's research on "Defense-Economic Decision Making" has been funded by Pew Charitable Trusts.

Within the profession, MIT political scientists remain active, organizing and participating in many panels at professional associations. Professor Hayward R. Alker, Jr. is President-elect of the International Studies Association and serves on the executive committee on the International Social Sciences Association. Professor Lipsky is a member of the Executive Council of the American Political Science Association. Professor George W. Rathjens chairs the Council

for a Liveable World and is co-director of the American Academy of Arts and Sciences project on Environmental Change and Acute Conflict. Professor Skolnikoff co-directs the Harvard/MIT project on an international regime for climate change. Professors Donald L.M. Blackmer and Weiner are organizing a series of workshops on the relationship between the Islamic Republics of Central Asia, the Transcaucasus in the USSR, and the states of Southwest Asia. Professor Suzanne Berger is a member of the Executive Committee, Social Science Research Council and of the SSRC-ACLS Joint Committee on International Programs. She is also a member of the Scientific Committee of the Juan March Foundation (Madrid) and of the Executive Committee, Center for European Studies, Harvard University. Professor Pye is Vice Chairman, National Committee on US-China Relations and Trustee, Asia Foundation.

Within the Institute, political science faculty have served on Institute committees and have been active in new Institute-wide activities. Professor Sapolsky chairs the Standing Faculty Committee on Faculty-Administration. Professor Blackmer serves on the Committee on Graduate School Policy; Professor Meyer, on the ROTC Committee. Professor Weiner is director of the Center for International Studies. The special committee named by the provost to study MIT's international activities was headed by Professor Skolnikoff; Professor Samuels also served on it. Professor Oye is Housemaster in East Campus Alumni House. Among the new Institute initiatives, Professor Choucri's role as chair of the faculty seminar on global change and as chair of the workshop on postwar reconstruction in the Middle East deserves special mention. Professor Berger, together with Professor Richard Lester, Nuclear Engineering, and Professor Thomas Kochan, Sloan School of Management, are the faculty operating committee for a new project on industrial performance which has received funding from the Sloan Foundation. Professor Sapolsky organized the Vannevar Bush Centennial Symposium.

Beyond teaching, research, professional service, and Institute roles, the faculty contribute actively to the analysis and formulation of policy at local, state, and national levels. Professor Lipsky is a member of the Board of Directors of the Roxbury Youthworks and will appear as an expert witness on behalf of 50,000 general relief recipients in Los Angeles County. Professor Sabel works with the State of Pennsylvania on industrial redevelopment. Professors Choucri, Meyer, Samuels, and Rathjens have testified before Congressional committees this year. Professor Choucri was named by the Secretary General of the United Nations Conference on Environment and Development to serve on a Working Party on Transfer of Environmentally Sound Technologies. Professor Berger continues to direct Seminar XXI: Foreign Politics and the National Interest, a seminar held in Washington for senior military officers and other government and corporate members of the national security community. For the Foreign Service Institute, Professor Weiner organized a two-day workshop on problems of postwar reconstruction in the Middle East.

SUZANNE BERGER

Program in Science, Technology, and Society

The past academic year was one of unusually intense activity for the faculty of the Program in Science, Technology, and Society (STS).

DOCTORAL PROGRAM

In its third year, the Doctoral Program in the History and Social Study of Science and Technology (a collaborative venture of STS, the History Faculty and the Anthropology/Archaeology Program) continued to develop in a satisfactory way. Present and incoming students received a variety of grants, including Mellon, NSF, Lyons, Ida Green, and MacArthur Fellowships. The number of applicants for admission to the Doctoral Program increased from 39 to 62, a dozen of whom were judged to be exceptionally well-qualified by the Admissions Committee. All of the five students offered admission decided to come to MIT. The Committee on Graduate Studies and Programs reviewed the Doctoral Program and approved its development to date. Important roles in the Doctoral Program were played by Professors Merritt Roe Smith (Director of Graduate Studies) and Loren Graham (Acting Director the spring term), both of STS, Professor James Howe of the Anthropology/Archaeology Program, and Associate Professor Peter Perdue of the History Faculty, all of whom were members of the Graduate Program Steering Committee.

PROJECTS, GRANTS, AND INITIATIVES

The year saw the unfolding of two new major projects funded in the previous year--the Mellon Project for the Study of the Life Sciences and the MacArthur Foundation-funded Soviet-US Workshops--along with a number of new initiatives.

Study of the Life Sciences

The first year of the Mellon Project, led by Assistant Professor Lily Kay, culminated in a successful Workshop on "Cutting Edge Biology" in the spring semester. Attended by approximately 70 scholars and graduate students from the US and abroad, the first of the four planned annual Workshops concentrated on the intellectual and institutional factors that have led some fields in biology to be defined as "cutting edge" while others receive little attention. Three post-doctoral Mellon Fellows were appointed from a strong field of 22 applicants: they are Drs. Marcos Cueto, Gail Fleischaker, and Jean-Paul Gaudilliere. Professor Everett Mendelsohn of Harvard will assume the leadership of next year's Workshop on International Comparisons in the Development of the Life Sciences.

US-USSR Workshops

The first Soviet-US Workshop on the theme of "Science and Technology with a Human Face," sponsored by the MacArthur Foundation, took place at MIT in May. Attended by a dozen Soviet scholars and writers, along with more than 50 American participants, the Workshop examined anti-science tendencies in the USSR and the United States. The project, led by Professor Graham, will hold the second workshop in Moscow in October; the theme will be the environmental movements in the two countries.

The Air and the Heavens

Professor Emeritus Leo Marx's report to the Rockefeller Foundation, "The Humanities and the Environment," received a favorable response. The MacArthur Foundation made a new grant to initiate a project on "Humanistic Perspectives on Atmospheric Change." Led by Professor Marx, the project will focus the work of historians, humanists, and social scientists on human, institutional, and

cultural factors involved in humanly-generated atmospheric changes. A series of monthly workshops on "The Air and the Heavens" is planned for the coming academic year.

Science-Government Workshops

A new series of regular faculty workshops on "The Relationship of University Science and the Federal Government" will begin next academic year. Funded by outside contributors and by MIT, the workshops will bring invited speakers to a regular faculty workshop that will examine changes and tensions in the alliance between research universities and the Federal government. It is expected that the results of the workshop will be published.

Colloquia

The Program initiated a weekly Colloquium Series, organized and led by Professor Kay. It brought to MIT 22 speakers, largely from other universities including Johns Hopkins, Cornell, Princeton, Harvard, and the University of Pennsylvania, who discussed their current research in the history and social study of science and technology. The Colloquia will continue next year under the leadership of Assistant Professor Deborah Fitzgerald.

Leofest

The Program hosted a one-day conference on "The 1990s: Changing Lenses on a Changing Reality" in honor of Professor Marx and Mrs. Jane Marx. One hundred guests and friends of the Marxes from across the country discussed changes in the conceptualization of the American experience in the light of new American realities. The "Leofest" concluded with a celebratory dinner for the Marxes at the MIT Museum.

Arthur Miller Lecture

The annual Arthur Miller Lecture was delivered in May by Professor Gerald Holton of Harvard, who spoke on "Thoughts on the Evolution of Trust in Research Results." The lecture was followed by a dinner attended by MIT faculty and members of the Miller family.

Siegel Prize

A generous grant from the family and friends of Benjamin M. Siegel made possible the establishment of the Siegel Prize in Science, Technology, and Society. The Prize is open to any MIT student, graduate or undergraduate, from any field, for work on the historical, social, and policy implications of science and technology. Excellent applications have been received, and the first winner of the Prize will be announced in the fall of 1991.

Dibner Lectures

Two special lecturers were sponsored by the STS Program with support from the Dibner Institute. They were Dr. Daniel Aleksandrov, of Institute of the History of Science and Technology, Leningrad, who spoke on "The New Social History of Science in the Soviet Union" and Dr. Terry Shinn, of the French National Scientific Research Council (CNRS), who spoke on "Education Through Research: the French Experience."

EDUCATIONAL ACTIVITIES

The STS Program's educational work continued at both the undergraduate and the graduate level. In all, the Program offered 22 undergraduate subjects and 22 graduate subjects during the last academic year. Undergraduate enrollments were up, especially in the HASS-D subjects offered by Program faculty. Professor Kay taught two new HASS-D subjects which review the history of science from

its beginnings to the present. Professor Emeritus Carl Kaysen and Professor Theodore Postol taught a new course on "Technology, Politics, and the Arms Race."

At the graduate level, several new seminars were offered. They include "Rethinking Culture" taught by Professor Marx and Assistant Professor Lisa Rofel; "Invention, Development, Management, and Transfer of Large Technological Systems," taught by Visiting Professor Thomas Hughes (University of Pennsylvania) and "Capitalism and the Industrial Revolutions," taught by Visiting Professor John Staudenmaier (University of Detroit).

CONTINUING ACTIVITIES

The Program continued a number of activities that had been initiated in earlier years. In the Student Lunch Workshops, organized this year by graduate student Jessica Wang, graduate students meet bi-weekly to discuss their ongoing research and current literature in the history and social study of science and technology. The STS Newsletter, ably produced by staff member Graham Ramsay, continued with monthly articles of general interest followed by news and notes on STS faculty, staff, and students. The STS Working Papers, prepublication versions of studies by faculty and graduate students, provide a means of disseminating early versions of work in progress.

KNIGHT SCIENCE JOURNALISM FELLOWSHIP PROGRAM

The Knight Program completed its seventh year, with 13 journalists from the US, China, Japan, Italy, and Poland in residence. Twelve new Knight Fellows were selected from a pool of applicants that increased from 20 last year to 32 this year. The Knight Program has moved from its previous quarters in Building E40 to renovated space in Building 9 at 77 Massachusetts Avenue. Plans are being made for activities that will keep the Knight Program and STS closely linked despite the greater geographic distance between the two related enterprises.

FACULTY ACTIVITIES

The STS Faculty took part in a variety of activities last year.

Associate Professor Laurence Bucciarelli was MIT's principal investigator for Project ECSEL, funded by the National Science Foundation. He has been appointed Co-director of the Integrated Studies Program. Visiting Professor Jill Conway was elected to the American Academy of Arts and Sciences. Professor Fitzgerald spent the year on Old Dominion and NSF fellowships in Iowa, doing research on the Wallace family and the transformations of American agriculture. Professor Graham headed the MacArthur-funded project on the Social and Political Dimensions of Science and Technology in the U.S. and the U.S.S.R., and received a grant from the Mellon Foundation to bring Soviet doctoral students to America. Among his publications were on "Science and the Soviet Social Order" in *National Forum*, "Adapting to New Technologies" in *Soviet Social Problems*, and the Russian translation of his book, *Science, Philosophy, and Problems of the Formation of Human Behavior in the Soviet Union*. Professor Kay, in addition to heading the Mellon Project on the Life Sciences, published articles on "The Politics of Fame: The Protein Network and the Tiselius Apparatus" in *Center at the Periphery: Swedish Science in the Twentieth Century*, and on "Into the Lab: Creating a Molecular Knowledge of Life?" in *Journal of the History of Biology*.

Senior Research Associate Victor McElheny directed the Knight Science Journalism Fellowship Program and wrote the report of the Illinois Institute of Technology Centennial Conference, "Humanity Has Options." He is currently working on a biography of Edwin H. Land, and participated in conferences at Irvine, the Salk Institute, and the European Molecular Biology

Association. Professor Postol organized the MIT seminar on "Technology, Defense, and Arms Control in a Changing World," and won the Leo Szilard Award of the American Physical Society. His testimony before the House Armed Services Committee on "Lessons for SDI from the Gulf War Patriot Experience: A Technical Perspective" received wide attention. Professor Smith was elected to the American Academy of Arts and Sciences. His article, "Industry, Technology and the Single 'Labor Question' in Nineteenth Century America" was published in *Technology and Culture*, and his essay "Technology and the Idea of Progress in America" was published in *Timeline*. He was also elected a member of the Section for History and the Philosophy of Science of the American Association for the Advancement of Science. Professor Sherry Turkle was promoted to full professor. The second edition of her book, *Psychoanalytic Politics*, was published with a new Preface and Afterword. Professor Charles Weiner chaired the session on biotechnology at the Society for the Social Study of Science Annual Meeting, was a member of the Advisory Committee for the National Museum of American History exhibit on "Science and American Life," and spoke at the University of New Orleans, Washington University, Boston University, Brandeis University, and the University of California at Irvine.

KENNETH KENISTON

Center for International Studies

OVERVIEW

During the academic year 1990-91, the activities of the Center for International Studies continued to reflect the rapid changes in the world arena in such fields as defense and security, development, environmental concerns, population movements, and global technology. These concerns were addressed in new and on-going seminars sponsored and co-sponsored by the Center, in the publications of the CIS programs, of faculty, and in the CIS news letter, *Précis*.

SEMINARS AND WORKSHOPS

One of the liveliest seminars, Peoples and States, chaired by Professor Jean Jackson (Anthropology/Archeology), examined the relationship of ethnicity, ethnic identity and struggle. Among the cases discussed were those of China, Afghanistan, Latin America, the Soviet Union and the United States. The Seminar series on Institutional Perspectives on Third World Development, funded by the MacArthur Foundation and chaired by Professors Judith Tandler (Urban Studies and Planning), Lance Taylor (Economics), and Assistant Professor Jonathan Fox (Political Science) focused on the changing dynamics of the state, market, and non-governmental institutions in the development process. The MIT-Harvard Joint Seminar on Political Development (JOSPOD) had as its theme this past year (its 27th) "Democratization: Why Not?" Co-chaired by Professor Myron Weiner, Director of CIS, and Professor Samuel Huntington of the Center for International Affairs at Harvard, the Seminar examined the constraints to and limitations of the democratization process in the Middle East, Asia, Eastern Europe, Africa and the Soviet Union. The Inter-University Seminar on International Migration, in its 11th year, supported by the Sloan Foundation and chaired by Professor Weiner, continued to examine issues of population movements in the context of changing world events, e.g. refugee rights and policies, European integration and United States immigration policies. Among specific cases treated were Soviet immigration to Israel, Central Asian migration and internal migration in China. The Political Economy Seminar Series, chaired by Assistant Professor Richard Locke (Political Science and the Sloan School), examined issues of industrial restructuring and changes in union movements in advanced industrial nations. The Faculty Seminar on Global Environment and the Workshop on Reconstruction in the Middle East, both chaired by Professor Nazli Choucri (Political Science), brought together faculty from the social sciences, architecture, engineering, and the environmental sciences. The Global Environment Seminar focused on the interaction between material process and changes induced by human activities in their technical, political and economic dimensions. The Workshop on Middle-East Reconstruction dealt with the challenges of physical, political, and economic reconstruction in the region. The Middle East was covered also in the ongoing Emile Bustani Seminar, chaired by Professor Philip Khoury (History Faculty) which, this year, dealt with issues of regional conflict, military strategy and post-war reconstruction. Finally, the MacArthur Graduate Student Seminar, organized and chaired by Dr. Elizabeth Leeds, Assistant Director of CIS, brought together graduate students with MacArthur grants from the fields of Development and Defense/Security to report on research in progress.

THE DEFENSE AND ARMS CONTROL STUDIES PROGRAM

The extraordinary changes in East/West relations that have occurred in the last year appropriately have been of great interest to the Defense and Arms Control Studies Program (DACs). To explore the security implications of these changes, the affiliated faculty and students have formed into several working groups, each with a distinctive topic and format. One led by Professor Harvey Sapolsky examines United States defense politics; another chaired by Professor Stephen Meyer focuses on Soviet security policy; a third led by Professor Barry Posen examines the conventional forces balance; a fourth headed by Professor Theodore Postol considers trends in weapons technology; a fifth, managed by Professor Richard Samuels of the MIT Japan Program, focuses on security relations in the North Pacific; a sixth run by Professors George Rathjens, Jack Ruina, and Carl Kaysen explores implications for United States security policies; and a seventh run also by Professor Sapolsky, looks at the environmental implications of defense activities. In addition, the Program sponsored three seminar series, the traditional DACs Seminars; a series on Technology, and a series on Defense Research and Development Policy organized by Professor Ruina.

The director of the Program is Professor Sapolsky, who has sought to encourage the initiatives mentioned above and to increase the Program's research and publication activities. The Program now has a new publication: *Breakthroughs*, in addition to *DACS Facts*, the Program's newsletter, and *Soviet Defense Notes*, the product of the Soviet Security Working Group led by Professor Meyer. A Working Paper series has also been restarted. Several new projects have been created, including efforts to examine the security implications of environmental change and the pollution effects of past weapons development and production. The Program also formed ties with several local and national defense firms and laboratories to explore topics of mutual interest. Its major sponsors remain the Carnegie, Hewlett, Ford, Sloan, Pew, and MacArthur Foundations. Over 40 graduate students have been affiliated with the program. Three visitors were with the Program during the year.

MIT JAPAN PROGRAM

The MIT Japan Program is continuing to grow in the numbers and fields of interns sent to Japan, in the Technical Japanese Language Project, in research and public awareness activities undertaken, and in the number of Program sponsors. More than 50 interns were sent to Japan in 1990-91, a record number. These included the first five management interns, who went to Japan under a joint initiative between the Program and the Sloan School of Management. The Technical Japanese Language Project, now in its fourth year, offers a highly competitive advanced summer reading course for computer scientists and electrical engineers. Despite stringent requirements for admission, the class has a total of 56 participants and continues to attract a large number of qualified applicants. The Project plans a similar course for materials scientists in the summer of 1992 and has just received funding to develop a text.

Research projects undertaken in the 1990-91 academic year have resulted in the publication of two books, a completed book manuscript and an advance contract for a fourth: *Japan's Software Factories: A Challenge to U.S. Management*, Michael Cusumano, Oxford University Press; *On Track with the Japanese: A Case-Study Approach to Building Relationships With the Japanese*, Patricia Gercik, Kodansha International Press; *Hedging Bets: Japan's Defense Industrial Strategy for the Year 2000*, Michael Chinworth, under publication review; *Rich Nation, Strong Army and Japanese Technology*, Richard Samuels, Cornell University Press. The wide range of the Program's research interests is reflected in the 21 working papers produced in the past year on topics including technology transfer, Japanese defense policy, energy policy, R&D and software factories.

Public awareness activities in the past year have included: "Learning from the Japanese R&D System: An Employees' Eye View." This IBM-sponsored conference was attended by 30 representatives of the Program's corporate sponsors who networked with nearly two dozen former Program interns, mainly with corporate research experience, to explore the expectations and norms for an employee in a Japanese R&D setting.

Cooperation continues with the Sloan School of Management to offer an annual MIT Executive Program in Japanese Technology. This week-long seminar is targeted at senior line and staff executives who are responsible for overall strategic decisions as well as marketing, engineering, manufacturing, and research and development. It is designed to analyze in detail firstly how Japanese firms manage areas such as product development and manufacturing, human resources and suppliers, business alliances and the internationalization process, as well as secondly how Japanese government institutions and cooperative R&D projects have facilitated the process of technology development at the firm and inter-firm level. Additionally, as a member of the committee on Japan of the National Research Council (NRC), Professor Samuels briefed Congress on the new developments in Japanese policy as part of the NRC's ongoing efforts to keep U.S. policy makers informed about the Japanese technology system. In this capacity, he also chaired a symposium on "R&D consortia and U.S.-Japan Collaboration" in Washington. This program was organized by the NRC as part of a series designed to provide a forum for discussion of key issues in U.S.-Japan science and technology relations. The Program now has a record number of 17 corporate sponsors and continues to enjoy the generosity of its Japanese host companies, the Japan-U.S. Friendship Commission, the National Science Foundation and the Starr Foundation, which, last year, granted the Program two million dollars, the largest gift ever made to a program of applied Japanese studies.

SEMINAR XXI: FOREIGN POLITICS AND THE NATIONAL INTEREST

Seminar XXI is an educational program for senior military officers, government officials and industry executives of the national security community. Run under the auspices of CIS and under the direction of Professor Suzanne Berger (Political Science), Seminar XXI recently completed its fifth year. The seminar meets monthly in Washington, DC, with each session focusing on a different foreign country or issue. The main objective of Seminar XXI is to develop among the program fellows new analytic skills for understanding foreign societies. By considering the politics of each country through different frameworks of analysis, the range of possible explanations for the behavior of US allies and rivals is widened, as is the range of US policy options which can be considered systematically. Each session brings together distinguished faculty from US and foreign institutions who present alternative approaches for understanding foreign politics. Recent upheavals in world politics places a premium within the US policy-making community on the kinds of critical and innovative thinking about US foreign relations and developments in foreign societies that Seminar XXI attempts to foster. Funding from private foundations provided support for the development of the program in early years. The program is now largely self-supporting, with participating organizations paying a program fee for each fellow involved, and with support of a generous gift from Mr. Harry Kalker (MIT'23).

OTHER ACTIVITIES

CIS was host, during 1989-90, to 19 visiting scholars from the United States, India, Brazil, Italy, and Lebanon. The Center sponsors and administers two annual competitions: the MacArthur graduate student grants for pre-doctoral research in development and defense/security studies and the International Energy Policy Grant, funded by the Japan Endowment, for research in international energy with particular attention to environmental and security issues. Additionally, CIS sponsored or co-sponsored five conferences: **Swords into Plowshares: The New Super Power Business Dialogue on**

Peace and Partnership and Productivity, jointly sponsored by the Institute for Defense and Disarmament Studies Program, the USSR Academy of Arts and Sciences and the council on Economic Priorities in association with DACS in September, 1990 at the American Academy of Arts and Sciences; **Academy Workshop on Post-War Reconstruction in the Middle East**, co-sponsored with the Foreign Service Institute in Washington for Foreign Service and State Department Personnel on issues and problems in post-war reconstruction in the Middle East, held in March, 1991, at the Foreign Service Institute and with the participation of several CIS affiliated faculty; **Remembering the Past and Shaping the Future**: One of the activities marking the inauguration of President Charles Vest, the symposium commemorated the science policy contributions of the late Vannevar Bush. Harvey Sapolsky was Chair of the Program Committee, speakers included Professors Sapolsky, Suzanne Berger, Jack Ruina and Eugene Skolnikoff; **Conference in Honor of Lucian W. Pye: The Political Culture of Foreign Area Studies** organized by Professor Richard Samuels and Myron Weiner and held at Endicott House in Dedham in May, 1991; **Symposium in Honor of Lincoln Bloomfield: MIT, Shaping the Future**, held in May, 1991, in conjunction with the inauguration of President Charles Vest, the conference theme was *The Unconventional University*. Five newsletters are currently being produced by the Center and Center programs: *Précis*, the Center newsletter, *Soviet Defense Notes*, *DACS Facts*, *Breakthroughs*, and the *Japan Program Newsletter*.

ELIZABETH LEEDS

Center for Materials Research in Archaeology and Ethnology

The four participants in the ambitious project, *Style in Art and Technology: Precolumbian America and Precolonial Africa*, designed by the Center for Materials Research in Archaeology and Ethnology (CMRAE), presented their research results at a special Board-sponsored panel of the College Art Association, in Washington, D.C. The project is a multi-year venture supported by a major grant from the J. Paul Getty Trust Grant Program. Assistant Professor Dorothy Hosler (Anthropology/ Archaeology Program and CMRAE) was the lead speaker; she discussed her 15-month ethnographic, archaeological, and experimental field research in Ecuador, concerned with the prehistoric and contemporary production of ceramic wares and the technological and cultural implications of such production. The panel was well-attended and enthusiastically received by the art historians.

Professor Hosler spent the year preparing a book manuscript, *The Sounds and Colors of Power in Ancient West Mexico*, for which she has received a contract from the MIT Press. She made two research trips to Mexico to examine and sample important museum and archaeological site collections of metal artifacts that will figure prominently in her analysis of the development of metallurgy in ancient Mexico and its relations to metallurgical technologies of prehistoric South America. As part of her ongoing study of early New World metallurgies, she contributed the analytical research design to three grant proposals submitted to the NSF, NEH, and NGS by colleagues in Mesoamerican studies. All three were funded, providing her with important Tarascan and Aztec materials for laboratory analysis. Professor Hosler also completed the first comprehensive study of prehistoric Ecuadorian metallurgy, which will comprise a chapter in her book. Concerned about the raw material sources behind the Ecuadorian metal industry, she designed an analytical program to determine and compare the lead isotope signatures of metal artifacts from Ecuador and Peru. She received a John D. and Catherine T. MacArthur Foundation Matching Grant (via Institute Professor Jerome B. Wiesner) as a summer seed grant to initiate this project. At CMRAE, Professor Hosler assisted in the development of computer code for a flexible data base management program that allows manipulation of chemical analytical, dimensional, and provenience data for metal artifacts. The program is currently installed in the CMRAE Computation Facility for all to use. Professor Hosler published *The Development of Ancient Mesoamerican Metallurgy* in the *Journal of Metals*. She received a grant from the American Smelting and Refining Company (ASARCO) to pay for the purchase and distribution to colleagues in Latin America of 200 copies of her 1990 monograph *Axe-monies and their Relatives*.

Dr. Michael Geselowitz (Lecturer and supervisor of the CMRAE Graduate Laboratory) began the academic year with a two-week trip to Yugoslavia as a Project Development Exchange Scholar, sponsored by the National Academy of Sciences and the Yugoslav Academy of Arts and Sciences. His purpose was to arrange a joint US-Yugoslavia archaeological excavation of an important Early Iron Age iron smelting site in Slovenia. The site was chosen with a view toward clarifying the relations between iron smelting technologies and the emergence of complex society in prehistoric temperate Europe. Although his trip was successful, the current political situation in Yugoslavia rules out the initiation of field research at this time. Dr. Geselowitz began a study of the early North American iron nail industry. His first paper on the subject, which resulted from a metallographic study of 18th - 20th century nails from the Factory Island site, in Maine, is soon to be published in *MASCA Occasional Papers of the University Museum, University of Pennsylvania: For Want of a Nail - Archaeometallurgy and Dating in Historical Archaeology*.

Dr. Ian Whitbread (Principal Research Scientist) continued his work on the application of modern imaging techniques to the petrographic analysis of ceramic materials. Together with Paul Goldberg of Hebrew University he has been able to show that, when examined in thin section, differences in the void structures of soils can be correlated with different activity areas at a site. Dr. Whitbread presented the preliminary results of this analysis at the 1991 Annual Meeting of the Society for American Archaeology. The paper, *Morphological Aspects of Bedouin Tent Deposits and their Implications for Archaeology*, was read at the session on site formation processes.

Nathaniel Osgood joined CMRAE as Research Specialist, with primary responsibility for developing the center's Computation Facility as a research environment for all center staff. He worked closely with Professor Hosler in elaborating the first versatile data base management program for the center's Hewlett Packard computers. Their program will be used by all center personnel and graduate students.

Professor Heather Lechtman (Anthropology/Archaeology Program and Materials Science and Engineering) continued her research on the prehistoric smelting of copper-arsenic ores in the New World. Her article on the subject, *The Production of Copper-arsenic Alloys in the Central Andean Culture Area: Highland Ores and Coastal Smelters?*, was published in the *Journal of Field Archaeology*.

The center's graduate subject for the 1990-1991 academic year was a new offering, *Materials in Ancient Societies: Geological Raw Materials*. It focused on ores and clays as the primary source materials for the production of metal and ceramic objects in prehistory. This new subject was taught by Professor Ulrich Petersen (Earth and Planetary Sciences, Harvard), Dr. Whitbread, and Dr. Geselowitz. The *Materials and Anthropology* discussion series enjoyed another popular year, with six speakers whose subjects ranged from the materials analysis of chert to the discovery of what is likely to have been a key source of tin for the ancient Middle Eastern bronze industry.

HEATHER LECHTMAN

Integrated Studies Program

ISP is one of the three alternative programs for freshmen at MIT. The program emphasizes learning about technologies and the societies in which they are embedded; hands-on application in all areas of study with the goal of examining the relationship between abstract thought and the concrete problems faced by a variety of societies, including our own; thinking analogically by making connections across various disciplines.

ISP enrolled 34 students this past fall, of which 9 were women and 12 were members of minority groups. We enrolled 37 students in the spring, 8 female and 9 minority group members.

Our students attended science and math lectures with the rest of the freshman class, but enrolled in ISP recitation sections taught by instructors concerned with making connections across the various disciplines. In keeping with our belief that students learn best by doing, our students enrolled in the experiment-based physics subjects, 8.01X and 8.02X, team-taught by Professors John G. King and A. P. French. Both physics subjects augmented lectures and recitations with vital experimental components.

At the heart of ISP are the two humanities subjects, "Technologies and Cultures," offered in fall, and "Technologies in Historical Perspective," offered in spring. These subjects are team-taught by a humanist, a physicist, and a technical instructor. Through a variety of readings, writings, and class discussions, students studies particular technologies in depth and analyzed why these technologies develop in different societies in the way they do. A crucial additional element was learning about these technologies by practicing them. In weekly workshops this past year students tried their hands at activities ranging from weaving and blacksmithing, to clock-making, internal combustion engine repair, and computer technology. Practitioners of some of these technologies supplemented the regular ISP faculty and staff as workshop facilitators. A full description and annotated syllabus for these two subjects, written by Associate Professor Arthur Steinberg and Technical Instructor Christopher Craig, was published by the New Liberal Arts Program at SUNY Stony Brook this year.

In keeping with ISP's commitment to expose students to a wide range of ideas, we hold weekly luncheon seminar series. In these luncheons, students met a variety of MIT faculty and staff, and other people from the community.

Our physics recitations were taught by Dr. Alan Lazarus, Senior Research Scientist and Senior Lecturer, and by Dr. Peter Dourmashkin, Physics Lecturer. Dr. Dourmashkin also participated as part of the three-member team in the humanities subjects. Professor Kenneth Russell of the Department of Materials Science and Engineering taught the 3.091 recitation. William Jokusch and Andrew Haskell, graduate students in the Math Department, taught the calculus recitations both semesters. We appreciate their enthusiasm and dedication. Christopher Craig supervised the workshops and

taught in the humanities subjects. Marshall Hughes, Senior Staff Assistant in ISP, provided invaluable support to the ISP staff and students. Debra Aczel, Program Administrator, saw to it that we all did what we were supposed to do and still kept within the budget!

We are working with Professor Louis L. Bucciarelli Jr. (who will be ISP's co-director next year) of STS, the School of Engineering, and the ECSEL coalition, to integrate more engineering design, thought and methods into the Program. We have been planning a new seminar for the fall on How Things Work to be taught by faculty from Mechanical Engineering in conjunction with the staff of ISP, and we will cover a variety of engineering problems in our sections of freshman physics, 8.01X. At the same time we will integrate these new physics/engineering topics into the Technologies and Cultures humanities subject.

This is the second year that we have offered a summer workshop on building an integrated curriculum for K-12 school teachers. In the summer of 1990 we worked with 17 bilingual teachers from the Cambridge Public Schools. The enthusiasm of those teachers, and our close association with the Center for Integrated Studies at Cambridge Rindge and Latin School led to our working this summer (1991) with 51 bilingual, vocational, and other teachers and administrators from Cambridge, Chicago, Philadelphia and Hartford over an eight-day period. We expect to continue this program in the future. An anonymous grant has also allowed us to start a program in which MIT students (mainly from ISP) and Cambridge Public School students from grades K through 12 are working together running a printing business as an experiment in peer tutoring and giving at-risk students a chance to learn in a non-school environment. We plan to augment our K-12 program and make it an integral part of the students' experience in ISP.

Arthur Steinberg, Director

Program in Women's Studies

CURRICULUM

The Program in Women's Studies offered fifteen subjects and three undergraduate seminars in academic year 1990-91, with roughly 275 students enrolled. The Program added three courses and three undergraduate seminars to its curriculum offerings this year. SP482J/483J Gender, Science and Technology, (joint-listed with both Anthropology and STS), was offered by Assistant Professor Lisa Rofel; SP407 Desire and Discourse: An Introduction to Lesbian and Gay Studies, was offered by Professor David Halperin (Literature) and Lecturer Joni Seager; and SP422J Unveiling Eve: Women's History in the Middle East, was offered by Visiting Assistant Professor Sherifa Zuhur (History). The undergraduate seminars were SEM077 Contexts and Constructs: Bisexuality; SEM078 Sex in the 90s: Reproductive Technologies; and SEM079 Gender Issues for MIT Women Students at MIT and Beyond.

SP482J/483J Gender, Science and Technology is possibly the most important addition to the Program's curriculum this year, since its focus, the conjunction of the study of gender with that of science and engineering, is the foremost intellectual goal of the Program in Women's Studies. SEM078 Sex in the 90s: Reproductive Technologies, taught by Lecturer Stephanie Bird (Aeronautics and Astronautics) will be expanded into a full subject to replace SP484J Reproductive Biology. SP422J Unveiling Eve: Women's History in the Middle East was well-received by students whose interest in the Middle East was stimulated by the historical events of the year and will be offered again in 1991-92. In August 1991, Professors Ruth Perry and Susan Carey and Associate Professor Isabelle de Courtivron will once again offer the MIT summer session course, "Women and Work: What Difference Does Gender Make?"

SEM077 Contexts and Constructs: Bisexuality received praise in both The Boston Globe and Outweek magazine as only the second course offered at any university in the country to focus on the study of bisexuality. SP407 Desire and Discourse: An Introduction to Lesbian and Gay Studies is the first course at the Institute to examine the new multi-disciplinary research on the theory of lesbian and gay studies. Together, these two courses represent a strong core for a lesbian and gay studies program, which, as it grows, should become an independent program, distinct from the Program in Women's Studies.

SP411/412J Gender and Theory: An Introduction to Contemporary Issues, developed this year by Instructor Elizabeth Wood (History) will be offered for the first time during Academic Year 1991-92 and will be joint-listed with Political Science. 11.334 Environmental Pollution: Selected Problems, Solutions and Policies, offered by Lecturer Patricia Hynes (DUSP) will be joint-listed with Women's Studies beginning in 1991-92. This course combines the scientific study of pollution with questions of public policy and an analysis of gender and is a welcome addition to the Program's course offerings.

The Women's Studies Research Room (WSRR), which is a portion of the Humanities Library and is funded in part by the Women's Studies Program, acquired a major new resource this year -- a 16 volume set, Black Women in United States History (Carlson Publishing). The Program also assisted the Library in creating a printed catalogue of holdings available in the WSRR. This list of holdings was previously unavailable to students and researchers using the WSRR and will greatly enhance the accessibility of the holdings in the collection.

STUDENTS

One Women's Studies major graduated in 1991 and three underclassers have filed for Major Departures in Women's Studies. Since the Women's Studies minor was instituted two years ago, eight students have graduated with that designation, and three other students are currently pursuing completion of minor coursework. Concentration figures have continued to rise steadily; fourteen 1991 graduates concentrated in Women's Studies, with ten current underclassers already declared.

In 1989-90, the Program instituted a Graduate Student/Faculty Luncheon Seminar Series which was continued this year. Graduate students pursuing research on women and/or gender issues in various departments throughout the Institute are often intellectually and emotionally isolated. The series was designed to provide these students, and interested faculty, with an opportunity to present work-in-progress to those with similar interests in other disciplines. This year's participants gave talks on the history of gender and physics; RU486, a new reproductive technology; feminism and environmental engineering; and women and economics.

The Women's Studies Writing Prize had 21 entries this year, representing students of many nationalities and majoring in many different Courses. Many students with minors in Women's Studies won prestigious awards at the Institute this year. Two graduating seniors won the AMITA Senior Academic Award, presented by the Association of MIT Alumnae on the basis of academic excellence. A junior who is minoring in Women's Studies won the Compton Award for citizenship and community participation. A sophomore minor was named a 1991 Burchard Scholar by the School of Humanities and Social Science. And still another Women's Studies minor was awarded a Marshall Scholarship.

PROGRAMS AND SPECIAL EVENTS

Programming continues to be our most visible contribution to the intellectual life of the Institute, as well as the source of active collaboration with other departments. The Program coordinates two annual speaker series: *Black Women Writers* with the Writing Program and *Women and Politics* with the Department of Political Science and the Center for International Studies. This year, *Black Women Writers* -- which is coordinated by Lecturer Frances Stubbs to complement her course, SP433J *Black Women Writers* -- brought to campus three renowned speakers: novelist Ann Petry, and critics Joy James and Elizabeth Hadley Freyberg. *Women and Politics* featured talks by four prominent political scientists. Both of these series will be continued during the 1991-92 academic year. The Program presented public screenings of five films to accompany the course SP422J *Unveiling Eve: Women's History in the Middle East*; this film series will also become part of our yearly programming to complement the course.

Women's Studies presented two well-known poets this year, Sharon Olds, in conjunction with Poetry at the Media Lab, and Irena Klepfisz, author of *A Few Words in the Mother Tongue: Poems Selected and New*. Cristina Peri Rossi, Uruguayan author, spoke on "El Poder de la Palabra Escrita: Mujer y Literatura/ The Power of the Written Word: Women and Literature," in an event sponsored by Women's Studies and Foreign Languages and Literatures. "Sexing the Body: Female/Male Anatomy in Human Evolution" was the title of a talk given by Adrienne Zihlman (University of California, Santa Cruz). During IAP, the Program sponsored a well-attended discussion "What is Feminism?" with panelists Jill Ker Conway, Jacqui Alexander (Brandeis) and Yukiko Hanawa (Wellesley). Continuing a now annual tradition, we sponsored an IAP film festival, "Third World Women Filmmakers" with films from China (introduced by the filmmaker), Venezuela and Lebanon. And the Program sponsored "Oral History in Action," a seminar to train students to participate in the Women's Oral History Project at MIT. In partnerships with community organizations, Women's Studies sponsored a reading by Margaret Randall, two films in the ground-breaking series "Liberation and Alienation in Algerian Cinema," and served as the MIT host of "Films by Asian American Women Filmmakers." In October 1990, the Program hosted a conference on the life and works of black feminist author Audre Lorde. This conference, honored with a keynote presentation by Lorde, attracted over 500 international feminist activists and scholars.

During the summer of 1991, the Program will be hosting the Computer Equity Expert Project which will present two six-day workshops for elementary school teachers on gender equity in math and science education.

RESEARCH AND PUBLICATIONS

Our semesterly publication, *Women's Studies Around Boston* was sent to 2000 individuals this year. This publication provides vital links between the Program at MIT and women's studies scholars at other institutions and in the community. We plan to switch to monthly publication in 1991-92.

Dr. Ruth Smith, Associate Professor of Religion at Worcester Polytechnic Institute, was a Visiting Scholar in Women's Studies during the spring of 1991. Dr. Smith is currently working on "The Moral Construction of Poverty in Liberal Society," and will present a Graduate Student/Faculty Lunch Seminar in the fall of 1991.

The Women's Studies Faculty continued their active contributions to their individual fields, and many of these accomplishments are listed in the reports of their home departments. Within the field of Women's Studies, Lecturer Bird is serving as the President of the Association for Women in Science (AWIS). She presented "Designing a Programmatic Framework for Women in Science and Engineering" to the National Science Foundation. Assistant Professor Leila Kinney led a seminar on "Gender, Fashion, Style: The Construction of Modernity" at the Feminist Art History Conference at Barnard College. Research Scientist Janet Murray edited a new edition of Mary Taylor's *Miss Miles* (Oxford University Press, 1991). Professor Perry co-edited *Social Control and the Arts* (New Cambridge Press, 1990). Professor Perry is author of "Mary Astell and the Feminist Critique of Possessive Individualism," in *Eighteenth*

Century Studies 23; and "Colonizing the Breast: Sexuality and Maternity in Eighteenth-Century Society," in *Journal of the History of Sexuality* (forthcoming). She also presented numerous papers in the US, Australia and New Zealand, including "Women's Studies in America" at the University of Auckland, New Zealand (June 1990).

Associate Professor Margery Resnick won the Everett Moore Baker Award for Excellence in Undergraduate Teaching in June 1991. Professor Resnick directed and participated in an international "Colloquium on Spanish Women" in Madrid, this year divided into three mini-colloquium on women and politics, the media, and education. Professor Rofel was awarded an Old Dominion Fellowship. She presented "Love and Politics on Chinese Television" at a forum on Melodrama Across Cultures, presented by the Cultural Studies Project at MIT. Lecturer Ann Russo is a co-editor of two books published this year: *Third World Women and the Politics of Feminism* (Indiana University Press, 1991) and *The Radical Women's Press of the 1850s* (Routledge, 1990).

Associate Professor Sherry Turkle presented "Computers and Social Change in the United States and Soviet Union" at the International Computer Forum in Moscow (June 1990). The second edition of Professor Turkle's book, *Psychoanalytic Politics: Freud's French Revolution* is forthcoming (Guilford Press, 1991). Instructor Wood presented "Putting the Woman Question to Work: Trade Unionism and Party in Soviet Russia" as part of a panel, Dilemmas of Feminism in Pre and Post Revolutionary Russia at Harvard University and "Class, Gender, and Politics in the Organizing of Women Workers in the 1920s" at the Russian Research Center. "Prostitution Unbound: Representations of Sexuality in Bolshevik Russia" is the title of her chapter in the forthcoming *Sexuality and the Body in Russian Culture*, edited by Costlow, Sandler and Vowles. Senior Lecturer Caroline Whitbeck authored "Ethical Issues Raised by the New Medical Technologies" in *Women and New Reproductive Technologies: Medical, Psychosocial, Legal and Ethical Dilemmas*, edited by Rodin and Collins (Lawrence Erlbaum, 1991).

Lecturer Seager, author of *The State of the Earth: An International Atlas* (Simon and Schuster, 1990), has accepted a tenure-track position in Geography and Women's Studies at the University of Vermont; she will be a great loss to Women's Studies and the entire MIT community.

Effective September 1991, Professor Carey will step down as Director of Women's Studies, and Professor Perry will take on that role.

SUSAN CAREY, Director

SLOAN SCHOOL OF MANAGEMENT

The 1990-91 school year was marked by effort to begin the process of installing a total quality management system and initiating a process of continuous improvement. Professor Gabriel Bitran organized a seminar attended by students, staff, faculty, alumni and friends of the school designed to bench mark the school performance relative to what other businesses were doing in total quality management. Professor Stephen Graves headed up a student, staff, faculty committee to recommend ways to institute a process of continuous improvement. The Dean met with Sloan's stakeholders -- students, alumni, faculty, employers who hire from Sloan -- in focus groups to get their inputs as where the Sloan School's performance could improve relative to their needs. Some efforts were made to decentralize decision making and push it down next to those that were most affected. In this spirit a small facilities maintenance fund was given to the students to spend in areas where they thought students would most benefit.

The reports of both of these groups in the late spring of 1991 led to the formulation of implementation groups that will hopefully start the process of realizing some of the gains that are clearly there to be made in the 1991-92 school year.

TEACHING PROGRAMS

Undergraduate Program

During the 1990-91 school year, 49 seniors majoring in management science were graduated. Of those 49 seniors, 10 chose an option in information technologies, nine selected marketing research, five concentrated in behavioral science, and two in operations research. Of the remaining 23 students who were pursuing other specially approved subjects, 21 chose an option in finance.

Thirteen of our graduates also received bachelor's degrees from other departments: four from the Department of Electrical Engineering and Computer Science, two from the Department of Mechanical Engineering and two from the Departments of Economics, Mathematics, and one each from the Departments of Civil Engineering, Chemical Engineering, Chemistry, Biology, and Mathematics. Two students received simultaneously the SB degree in Management Science and the SM degree in Management.

This May the Department was pleased to acknowledge four exceptional students in management science. Jean S. Ihm, Kelly K. McDonald, Angela M. Roberts, and Jackie B. Rosner received the Sloan School of Management Senior Prize which is awarded to outstanding senior management students who have achieved high scholastic standing and have demonstrated leadership and professional promise.

This spring 119 students were enrolled in the Management Science Program, including 11 who were enrolled in management science as their second SB department. (Enrollment figures are based on the registrar's fifth week counts.)

Seventy-four of our continuing undergraduates have declared their options as follows:

Regular Options

Information Technologies	32
Marketing Research	12
Behavioral Science	4
Operations Research	6

Special Options

Finance	17
International Management	2
System Dynamics	1

A large number of students from other MIT degree programs continue to enroll in our undergraduate subjects. There were 426 such enrollments during the 1990-91 academic year, representing the classroom equivalent of 45 full-time students. Since MIT undergraduates normally take only about 60 percent of their units in their own

departments, this is equivalent to having approximately 75 additional undergraduates in our program, for an equivalent total of 194.

Faculty serving as undergraduate advisors were Professors Thomas J. Allen, Ravi Bhushan, Wujin Chu, Steven D. Eppinger, Robert M. Freund, Stephen C. Graves, Rebecca M. Henderson, James B. Orlin, Michael A. Rappa, and Y. Richard Wang along with Dr. Jeffrey A. Meldman, Director of Undergraduate Programs, Dr. Peter J. Kempthorne, Mr. David R. Breakstone, and Ms. Hillary De Baun, Program Administrator. Professor Anantaram Balakrishnan continued as coordinator of MIT's Undergraduate Research Opportunities Program (UROP) and Mr. Breakstone served as coordinator in management science for phase two of the writing requirement. Dr. Meldman served as chair of the Undergraduate Advisors Committee and as IAP coordinator, and Ms. De Baun served as IAP administrative coordinator.

Faculty serving on the Undergraduate Policy Committee included Professors Allen, Freund, Orlin, and Abraham J. Siegel. Dean Jeffrey A. Barks, Dr. Meldman, and Ms. De Baun served *ex officio*, and Professor John D. C. Little chaired the committee.

During January 1991 we offered our IAP activity "Organizational Reality" for the third year. This intensive series of classes, readings, and exercises to introduce MIT undergraduates to the important realities of working in organizations drew mostly students majoring in engineering and science. This series, designed primarily for students in science and engineering disciplines, was led by Professor Abraham J. Siegel and Dr. Jeffrey A. Meldman and involved the coordinated participation of 15 management faculty, a panel of mid-career students in our Management of Technology program, and two MIT alumni from the corporate sector.

Thirty-three students were enrolled in "Organizational Reality" and, as before, attendance, preparation, and class participation were mandatory, in return for six units of Pass/Fail credit. Evaluations by the students and comments from participating faculty were once again enthusiastically positive.

The following faculty participated in "Organizational Reality": Professors Thomas J. Allen, John S. Carroll, Arnoldo C. Hax, Thomas A. Kochan, Lisa M. Lynch, Thomas W. Malone, Stewart C. Myers, Edward B. Roberts, Edgar H. Schein, Abraham J. Siegel, Robert J. Thomas, John E. Van Maanen, Eric A. von Hippel, and Drs. Jeffrey A. Meldman and JoAnne Yates.

Management faculty who participated in other IAP programs were Professor Kenneth A. Froot and Jiang Wang who coordinated the Bourse Game seminar in conjunction with Citibank; Dr. Jeffrey Meldman and Professor Judith A. Lachman who conducted sessions in Dr. Meldman's series "A Brief Introduction to Law"; and Professors Jay W. Forrester and John Sterman who participated in "Using Computers for Interactive Learning".

In addition to participating in IAP, members of our faculty contributed to the undergraduate educational commons in the following ways: Professor Stuart E. Madnick read freshman applications; Professors Little and Balakrishnan were engaged in freshman advising, and Professor Rappa and Dr. Meldman also advised freshmen and conducted freshman advisor seminars for their advisees. Fifteen of our faculty served on Institute committees related to undergraduate educational policy or to our undergraduate program: Professor Henry D. Jacoby served his second year as Chair of the Faculty, and Professor Lotte Bailyn served on the Faculty Policy Committee; Professor John Sterman served on the Committee on Curricula, and Professor Paul Osterman chaired the Committee on the Library System for the second year; Professor John S. Carroll served on the Committee on Student Affairs and also on the Committee on Operations Research; Professor N. Venkatraman served on the Committee on the Writing Requirement and Professors T. J. Allen and Lisa M. Lynch on the Athletic Board; Professors Glen L. Urban, Gabriel R. Bitran, and John Little served on the Committee on Operations Research which was co-chaired by Professor T. L. Magnanti; and Professors Judith Lachman and J. D. Nyhart served on the Prelaw Advisory Council, along with Dr. Meldman who also served on the Committee on the Use of Humans as Experimental Subjects. Thirty-seven faculty supervised UROP projects for students from departments throughout the Institute.

Master's Program

The past year was one of self-study as several groups worked both independently and in concert to evaluate all the aspects of the Master's Program. The goal of this scrutiny was to set in place a process to improve the educational experience, both in reality and in perception.

Primary responsibility for this undertaking was given to an Improvement Task Force, consisting of students, faculty, alumni/ae, and staff. Research was structured to gather data from alumni/ae, students, and corporate recruiters. The six-month process resulted in a set of concrete recommendations regarding program curriculum, teaching, governance, facilities and alumni/ae interaction. Implementation of these recommendations has begun and will continue in the coming year.

The Master's Program Committee also focused its attention this year on assessing the structure and substance of the Program. Their efforts will have ongoing impact as the Committee for next year has been given a wider range of responsibilities and authority to manage the Program, as well as the resources necessary to accomplish their goals.

The third evaluative process began in the early Fall when a large group of master's students established 'input groups' to prioritize the needs and interests of the student body regarding such topics as curriculum, internal and external networks, student governance, and Sloan's facilities. Findings were shared with the Master's Program Committee and the Improvement Task Force and encompassed in the recommendations made by those two groups.

The Sloan School as a whole also chose to study Total Quality Management as it relates to Sloan--Professor Gabriel Bitran offered a Quality Workshop, involving approximately 75 students, staff, and faculty. In this seminar, teams focused on how to apply TQM techniques to Sloan problems and issues. The class (offered for credit to the students) will address advanced topics in this field next Fall.

This year a new double degree was offered by the Sloan School and MIT's Center for Transportation Studies. The CTS/Sloan Double Master's Program will blend managerial concerns with logistics and transportation issues, incorporating field research and an internship with more traditional classwork. The 24 month program will lead to two degrees, the SM in Management from Sloan and an SM in Transportation from the School of Engineering.

The Distinguished Speakers Series brought to Sloan a varied group of corporate executives--Reinosuke Hara, President of Seiko Instruments, Inc.; William H. Gates, Chairman and Co-Founder of Microsoft Corporation; and Lee A. Iacocca, Chairman and Chief Executive Officer of the Chrysler Corporation.

Second-year master's students who received merit scholarships on the basis of academic excellence and professional promise were Daniel Abut, the Miriam Sherburne Scholarship; Steven Weingarten, the Henry B. du Pont III Scholarship; Dana Cooperson, the Henry Ford II Scholarship; and Thomas Anderson and Thomas Ricciardelli, the Seley Scholarships. Stephen Marcus was awarded the Hill Prize for excellence in accounting. This year the Martin Trust Community Fellowships were established so that students could recognize those classmates who had made significant contributions to the Sloan community. The first recipients of this award were Jack Langworthy, Karen Lee, Mary Su, and Charlie Tillett.

The Procter and Gamble Company scholarship for international students was awarded to Yumi Nakazawa and Jordi Portet. The Junior Achievers Little Family Foundation Fellowships were presented to Thomas Anderson, Margaret An Andrews, Winston Ledet, Karen Lee, Stephen Raab, and Laura Ring Wheaton.

Professors Arnold Barnett and Robert Freund were awarded the second annual "Alumni/ae Award for Innovation and Excellence in Management Education", given at the now traditional Faculty Appreciation Day. Other faculty recognized for their excellent teaching included Paul Asquith, Charles Fine, Paul Healy, Rebecca Henderson, and Andrew Lo.

Students expanded their hands-on study of international business practices this year with a trip to Eastern Europe, visiting businesses and learning about corporate and cultural life in Germany and Poland. The Japan/Korea Trip, now in its third year, offered a similar study of management in the Far East.

Competition for admissions at Sloan became more intense, as applications for admissions increased this year. The entering class, including Leaders for Manufacturing students, totaled 250.

The following table presents a profile of the graduate classes of 1991 and 1992:

Profile of Graduating Master's Classes	1991	1992*
Number of Candidates:	245	250
US Citizens	160	154
Foreign Citizens	85	96
Women	57	63
Members of Minority Groups	30	31
Median GMAT score (national average is approximately 460)	650	650
Undergraduate Grade-Point average (out of 5.0)	4.5	4.3
Undergraduate Majors:		
Social Sciences and Humanities	31%	27%
Physical Sciences	12%	14%
Engineering	48%	47%
Pre-Professional	9%	12%
Average Years Full-Time Work Experience	4.0	4.4
Mean Age at Admission	27	27

*Projected

Career Development Office

Numerous media articles this spring chronicled the difficulties and disappointments of MBA students seeking career opportunities in a recessionary market. Company lay-offs, economic uncertainties, and the Gulf War combined to create a mood of caution among employers. Firms cut back their hiring targets and associated recruiting activities.

At Sloan, employer conservatism manifest itself in the form of a 14% drop in the number of companies coming to campus to make presentations or interview master's students. The flow of job listings sent to the Career Development Office by mail also dropped significantly. Consequently, the majority of students needed to pursue opportunities independently, polishing their networking skills and being very proactive in their outreach to potential employers.

Students' success in landing good jobs this year despite corporate hiring conservatism attests to their excellence, creativity, and persistence. Regardless of market conditions, the majority of students secured jobs consistent with their objectives. For some individuals, the final position they accepted represents a compromise; i.e., settling for a "job" rather than a "career" opportunity. Other candidates still unaffiliated by graduation insisted on holding out for the right job because of what they've invested in their master's program. As a result, a higher number of candidates than normal (approximately 25% compared with the typical 20% of the class) will continue job hunting into the summer.

The single most noteworthy placement statistic this year is the increase in students electing to work in manufacturing operations and in operations/manufacturing job functions. The number of students taking jobs in manufacturing firms (regardless of job function) rose from 31% in 1990 to 43% in 1991. Similarly, students entering operations/manufacturing job roles rose from 8% in 1990 to 14% this year.

The number of students entering electronic/computer manufacturers (14%), chemical/pharmaceutical firms (12%), and oil/gas companies (3%) increased slightly. Candidates entering management consulting firms (33%), investment banks (12%), and transportation equipment manufacturers (4%) remained about the same. The decline came in students joining financial service organizations (including commercial banks, venture capital companies, and real estate firms) which reflects reduced hiring by these industries this year.

As for type of job function selected by graduating students, the greatest number of candidates will enter management consulting roles (29%), followed by financial positions (22%), manufacturing or operations management jobs (14%), and marketing/sales functions (13%). Massachusetts continues to attract the largest

percentage of graduates (24%), followed by international locations (18% which generally reflects the return of foreign nationals to their home regions), and New York (14%).

On average, members of the Class of 1991 received three job offers, paralleling last year's data. Base starting salaries range from \$18,000 - \$100,000, with a median of \$60,000 (up from \$59,000 in 1991). More current and complete information will be available from the Career Development Office in August when final placement results for this year's Master's Program candidates will be compiled.

Alumni/ae Relations

The alumni/ae relations program inaugurated a new format of events this year created to meet the top priority needs of the School's graduates--networking opportunities to further career contacts and substantive topics to address real-world business issues. The first symposium, "The Future of Financial Services", was held in New York City in October. Over 100 alumni/ae from five countries gathered for the presentations by faculty and industry leaders.

The second symposium in the series, "New Industrial Strategies for the New Europe: Who Will Align with Whom?", is being jointly sponsored by the Master's and Executive Education Programs. Originally scheduled for April but postponed due to the Gulf War, this mini-convocation will be held October 24-26 in Paris and will feature faculty and European business leaders.

Plans are well underway for the first Sloan Master's Convocation, to be held in Cambridge from October 17-19. The theme is "Technology: Revolutionizing the Way the World Does Business".

Reunion was held the weekend of June 7, 8, and 9 for the Classes of 1966, 1971, 1976, 1981, and 1986. Events included class-specific consumption functions, picnics, brunches, and a seminar. The Saturday night reception and dinner for all classes was followed by live entertainment and dancing. Records set included the largest returns from the 10-year (33%) and five-year (37%) classes.

Dean Lester Thurow hosted the Eleventh Annual Summer Gatherings in Boston and New York, with the San Francisco event scheduled for August.

Alumni/ae actively supported the School through participation in fundraising telethons (both as callers and as donors), admissions recruitment evenings, Career Development Office activities, and the newly established mentor program which pairs alumni/ae as advisors for current students.

Alumni/ae Relations remains dedicated to a two-foci mission: to provide the social, academic, and professional benefits our graduates expect from their School and to encourage the flow of resources and business world connections that support Sloan.

Alfred P. Sloan Fellows Program

On June 4, 1991, 57 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1991 represented a broad diversity of backgrounds and interests, and again was drawn from organizations from the United States and abroad. The Sloan Fellows Program was the first executive education program in the United States and is now in its 60th year.

Just prior to their graduation, the Sloan Fellows completed a three-week International Management Field Trip to Asia. They visited with leading government and industrial representatives in Australia, Singapore, Indonesia and Hong Kong.

	82-3	83-4	84-5	85-6	86-7	87-8	88-9	89-90	90-1
<u>Industry</u>									
United States	28	26	30	26	31	33	25	26	25
International	13	15	13	12	14	12	20	19	22
<u>Government</u>									
United States	10	8	9	10	8	7	6	7	8

International	2	5	3	4	0	4	3	2	0
Other									
World Bank	0	0	0	0	0	0	0	1	0
Municipal Mgt	0	0	0	1	1	0	0	0	0
Medical Mgt	3	4	3	2	0	0	0	1	1
Church Mgt	0	0	1	0	0	0	0	0	0
University Mgt:									
United States	1	1	1	1	1	0	0	0	0
International	0	0	0	0	0	0	0	0	1
	55	56	57	54	55	56	54	56	57

The demand for the program continues to be strong and the quality of the nominations is extremely high. On June 14, 1991, the Class of 1991-92 arrived; there are 54 participants in the 1991-92 program.

The Director of the Sloan Fellows Program, Charles Grader is an alumnus of the program (Class of 1974). Professor Robert McKersie served as Chairman of the Faculty Program Committee.

Program for Senior Executives

The Program is an international program. Non US executives make up 50% of the class; and curricula are increasingly focused on current and future global management realities.

Both US and non US managers are nominated, in part, to profit from the rich, varied cultural backgrounds and experience of the participants.

Professor John Van Maanen assumed completed his term as Chair of the Program Faculty Committee. Professor Michael Scott Morton will assume that position in September.

Ms. Judith Boudreau has been added to the Program staff as Program Manager. Ms. Judith Mason continues on as Program Coordinator, and Dr. Peter Gil as Director of the Program.

International Collaboration: MIT/NTU

The Sloan School has signed a five-year contract with the Nanyang Technological University (NTU) to assist in the development of a comprehensive business school in Singapore. Under the agreement, MIT faculty visit NTU to offer research seminars, participate in the development of curricula, and meet with students and faculty. Additionally, NTU faculty participate in Sloan School programs as visiting scholars.

A further objective of the collaboration is cooperative research projects. At the end of the first year of the collaboration, all of these activities were well underway.

MIP-MIT Executive Program

International initiatives for Sloan were a focus of activity this year as the Sloan School and MIP-Politecnico (a consortium comprising the Polytechnico di Milano and approximately 40 public and private Italian companies) launched an intensive general management program for mid-career executives. The MIP-MIT Executive Program will meet for a total of three weeks in Milan and three weeks at MIT and is intended to provide a unique opportunity for an international comparison of critical issues in management.

STOA Program

Sloan continues its institution building relationship with STOA, a non-profit corporation formed by IRI for the purpose of providing post-graduate management education in Italy. Sloan provides curricular advice and educational resources. Over the last year, Professors Lessard, Locke, Lynch, Rosenfield, Ulrich, and Westney have each taught at STOA for one to two weeks. The program will continue for two more years, as Sloan works to solidify accomplishments made and help STOA put in place a structure to move into the future.

Management of Technology Program

The MIT Management of Technology Program (MOT) was established in 1981 and is the only program of its kind. Administered jointly by the Sloan School of Management and the School of Engineering, this 12-month, full-time program leads to the degree Master of Science in the Management of Technology. It is aimed at engineering and science managers with eight to twelve years of work experience, and strives to prepare them for senior roles in industry and government where they will assume leadership positions in the creation and growth of technology-based endeavors.

In spite of the weak economy internationally, applications for 1991-92 remained at near record levels although enrollment declined to 40 from the record number of 44 in the class of 1990-91. Marketing efforts continue to build the program towards a desired full complement of 50 to 55 participants.

The major curriculum improvements introduced in 1990-91 have been well accepted by the participants and faculty. Some small adjustments are being made for 1991-92. The field trip to California, introduced in 1990-91 and much more extensive than any prior trips, went very well. Such a major trip will become an established element of the MOT Program curriculum in future years.

During 1990-91, as an experiment, a subject was offered with enrollment restricted to MOT and Sloan Fellows students. The similarity in background of these two groups of students made this a highly successful experiment for both the instructor and the students. Two such joint subjects will be offered in the 1991-92 curriculum.

Roger A. Samuel continued as Director of the MOT Program; Professors Edward B. Roberts of the Sloan School and Thomas H. Lee of the Department of Electrical Engineering and Computer Science continued as Co-Chairmen of the Program.

The Ph.D. Program

During 1990-91, the Sloan School's Doctoral Program continued to hold a prominent position in the face of ongoing and intense competition from the other leading business schools. From our 425 applications, we made 34 admission offers and had 20 (59%) acceptances, distributed among 3 areas:

Economics, Finance and Accounting	6 (1 foreign female, 5 foreign males)
Management Science	7 (2 US females-1 under-represented minority 3 US males and 2 foreign males)
Behavioral Policy Sciences	7 (1 US female, 1 foreign male 5 US males-2 under-represented minorities)

The overall percentage of US applicants rose to 42% and the foreign applications declined to 58% while the large number of applications normally received from India, Korea and several other countries within Asia. We continue to cooperate with the efforts of the American Assembly of Collegiate Schools of Business (AACSB) to recruit more qualified US applicants, and work on our own strategies for identifying prospects and sources. The bulk of the program's graduates pursue academic careers.

The Doctoral Program Committee, headed by Professor James B. Orlin and coordinated by Sharon Cayley, continues to grapple with the diverse problems of a very individualized program, including addressing time taken to complete the program (four and a half years) through early research ties to faculty, and financial aid awards that are competitive with our principal rivals.

Summer Programs

School of Management faculty participated in three MIT Special Summer Program courses. The two one-week programs were New Technologies for Decision Support and System Dynamics: Microcomputer Simulation of Corporate Strategy and Social Systems. The third course, Management of Research, Development and Technology-Based Innovation, was two-weeks long.

In addition to the MIT Special Summer Program courses, the Sloan School offered five one-week Special Executive Programs. Two have been available for several years (Corporate Strategy and Financial Management) and the other three (Complex Organizations, Japanese Technologies and Management Issues for

Corporate Counsel) were introduced in 1990. All continued to draw senior executives from international private and public sectors.

RESEARCH

Economics, Finance, and Accounting

Faculty research in Economics, Finance, and Accounting applies the tools of economic theory, statistics, and operations research to a wide range of problems. Work is directed to issues of economic policy, to problems in pure theory, to empirical questions, and to the development of improved decision-making methods for practicing managers.

Applied Economics. Professor Ernst R. Berndt's textbook, *The Practice of Econometrics: Classic and Contemporary*, was published by Addison-Wesley in 1990. Professor Berndt was also awarded an honorary doctorate from Uppsala University in Sweden. His research focuses on the cost effects of mergers, interdependent markup and pricing behavior among U.S. automakers, the effects on private sector productivity growth of public infrastructure investments, and the measurement of price change (adjusted for quality change) in the U.S. pharmaceutical industry.

Professor S. Lael Brainard is engaged in research on strategic trade policy and on structural unemployment, using analytical and empirical techniques from economics. She taught classes on international trade and competition and on international macroeconomics.

Professor Kenneth A. Froot's research covers a broad range of theoretical and empirical topics in international economics and finance. He has studied exchange rate fluctuations and their consequences, trade liberalization, and strategies toward LDC debt.

Professor Henry D. Jacoby's research is on the analysis of energy and resource projects, using methods of modern corporate finance, and on economics and policy issues of global environmental change.

Professor Robert S. Pindyck continued his research on irreversible investment decisions, focusing on investments of uncertain cost, and capital replacement decisions. He also continued his research on commodity markets, testing the present value model of rational commodity pricing, and developing and testing models of commodity storage.

Professor Nancy L. Rose continued her work on the determinants and effects of government regulatory policies. Her current research projects include an investigation of airline service quality provision and an analysis of executive compensation practices in regulated industries. This fall, she was appointed the Director of the National Bureau of Economic Research Program in Industrial Organization. She has been named an Alfred P. Sloan Foundation Fellow for 1991-1993.

Professor Julio J. Rotemberg has continued his work on the ways in which imperfect competition among firms exacerbates the business cycle. He has verified his model empirically by analyzing the effect of changes in military purchases on the U.S. economy. He has also worked with Robert Pindyck on the extent to which the prices of various financial assets move together more than is justified by economic fundamentals.

Professor Richard L. Schmalensee continued on leave this year as a member of the President's Council of Economic Advisers in Washington, D.C.

Professor Thomas M. Stoker has continued his work on the development of semi-parametric estimation techniques and their application to economic problems. He has also done further work on the implications of aggregation for the analysis of consumer demand.

Professor Alwyn Young continued his research on the implications of bounded learning by doing for comparative advantage and long-run growth. He also developed measures of the contribution of structural adjustment to GNP growth.

Finance. Professor John C. Cox continued his work on intertemporal consumption and portfolio policies. In work with Chi-fu Huang, he analyzed the existence and characteristics of optimal policies, and also studied their equilibrium properties. He has also begun work on the intertemporal dependencies of security returns.

Professor John Heaton is investigating a model in which individual investors cannot completely diversify their labor income. The implications of this model for the dynamics of stock and bond prices are being compared with observed data. Over the past year he taught a Ph.D. level course in empirical finance and developed a Ph.D. level course in financial economics for students in macroeconomics.

Professor Emeritus Daniel M. Holland has continued his work on the effects of taxation and the design of tax policy, and he has continued to serve as editor of the *National Tax Journal*.

Professor Chi-fu Huang has worked with John C. Cox on intertemporal consumption and portfolio policies (see above). In addition, he has been developing theoretical models of the Treasury Bill auction market.

Professor Andrew Lo has developed a new Master's course on empirical techniques in pricing financial securities, which emphasizes hands-on computing with actual stock and bond market data. His research has focused on measuring the relationship between stock price changes and other economic variables on a trade-to-trade basis, taking into account the fact that price changes are discrete and occur at irregular time intervals. He has also served on seven committees, and has chaired three of them.

Institute Professor Franco Modigliani has completed his research on the causes of the decline in the saving ratio encompassing all the OCED countries. macroeconomic policy and performance. His evidence clearly points to three major causes: (i) the universal decline in the growth rate; (ii) the generalized increase in government deficits; and (iii) inflation illusion, leading to confuse real and monetary interest rates. He has also devoted some attention to the problem of reconversion in Eastern Europe. In addition, he has made good progress on a textbook, *Capital Markets -- Institutions and Instruments*.

Professor Stewart C. Myers continued to work on signaling models of accrual accounting and the role of discretionary accounting choices in conveying information to investors. He is assessing organizational theories of corporate financing, in which the mature firm is viewed as a self-interested value-maximizing coalition and dividend policy is analyzed as an implicit contract with outside investors. Finally, he is working with Professor Lakshmi Shyam-Sunder on empirical tests of corporate financing policy.

Professor David Scharfstein has been doing research on a wide variety of topics in empirical and theoretical corporate finance. His recent projects include analyses of Japanese corporate financing arrangements, the economics of financial distress, and the effect of product market structure on corporate financial structure.

Professor Jeremy C. Stein continues to work on a broad range of theoretical and empirical topics in corporate finance and asset pricing. His current research includes an analysis of the consequences of "short-termism" in financial markets, and an examination of the 1980s leveraged buyouts.

Professor Jean-Luc Vila is currently studying the impact of various market imperfections, such as transaction costs or leverage constraints, on the behavior of economic agents in financial markets. He is also continuing his research in the area of economics of information.

Professor Jiang Wang has been working on equilibrium models of dynamic stock prices and trading volume under asymmetric information. He is also working on the problem of optimal contracting between investors and money managers.

Accounting. Professor Andrew W. Alford continued work on a model of the valuation role of earnings, and he examined the accuracy of the price-earnings valuation method. He also began work with Mark E. Zmijewski at the University of Chicago on the stock price effects of delayed interim earnings releases.

Professor Ravi Bhushan work has been in the area of efficiency of capital markets. He has developed a model to examine the impact of "short-termism" on the behavior of asset prices. In another project, he is analyzing the puzzle of the delayed price reaction to earnings announcements.

Professor Paul M. Healy has worked on three research areas. The first examines how firms perform after mergers and acquisitions. The second examines problems faced by firms' managers in communicating information on their firms' performance to outside investors. The final research topic examines how trends toward globalization of investors financial and product markets have affected cross-country merger and acquisition activity.

Professor Alfredo Kofman is working on the design of new performance measurement, evaluation, and incentive systems. He is testing the implications of his conceptual models in the manufacturing companies associated with the Leaders for Manufacturing program. He is also studying the impact of management information systems on organizational learning and modelling the incentive mechanisms that may lead managers to behave in counterproductive or myopic ways. Professor Kofman has continued his research on collusion-proof mechanism design and optimal communication algorithms.

Professor Uri Ronnen has continued his work on quality standards. Contrary to the prevailing literature on the subject, he has argued that when production involves quality-dependent fixed costs, an appropriately chosen standard will enhance price competition and increase consumers' participation and welfare.

Management Science

The Management Science area encompasses the following concentrations: marketing, operations management, information technology, probability and statistics, and operations research. New initiatives, are being implemented by the members of the area. Several faculty in Management Science participate and coordinate a workshop on the management quality as applied to the Sloan School. Steven Eppinger and Karl Ulrich are playing a major role in the introduction of a new module on the management of technology with an emphasis on manufacturing. Thomas Malone has established the Center for Coordination Sciences which has the potential of opening the doors to a new fruitful research domain. In addition to these initiatives, several important research topics are being undertaken. These include: the modeling of variability in manufacturing systems, the management of quality, capacity expansion models for telecommunication networks, models to aid the management of software development and measures of software productivity, economic impact of information technology, and the integration of marketing and engineering.

Members of all the subgroups have continued to play a role in the Leaders for Manufacturing Program (LFM) in a wide variety of functions. In particular Tom Magnanti is a co-director of the program. A significant number of LFM students have been and are being advised by faculty of the Management Science area.

Awards and Honors: Both Professors Bertsimas and Wein were awarded NSF Presidential Young Investigator Awards. Professors Barnett and Freund were awarded Sloan teaching awards as outstanding teachers. Professor Magnanti was elected to the National Academy of Engineering. Professor Madnick co-authored the book *Dynamics of Software Development: An Integrated Approach* (Prentice-Hall, 1991) which has received very favorable reviews.

Operations Management. Professor Gabriel R. Bitran has been working on the development of models to analyze manufacturing operations with variable yields. These are typical of semiconductor manufacturing and other high technology environments, such as fiber optics. He has continued his research in the service industry studying reservation systems. The context in which the study is being performed is the hotel industry. The objective is to develop models to allow managers to match supply and demand. Professor Bitran continues to work on a methodology for assessing the status of quality in services.

Professor Stephen C. Graves's work continues to focus on understanding the value of production flexibility in various forms, and on modeling variability in manufacturing systems. He is supervising LFM projects at Kodak, United Technology, and General Motors.

Professor Charles H. Fine continues his research on quality management. In addition, he has been focusing recently on research and LFM course development on management control emphasizing how accounting and information systems can affect manufacturing competitiveness.

Professor Lawrence Wein continues to develop new methods and principles for the scheduling and control of production operations, as modeled by a network of queues. A particular accomplishment includes new ways for setting due dates and priorities in complex production operations.

Professor Karl T. Ulrich has several projects in the areas of product development, modeling of manufacturing costs, and computational tools for design for manufacturing. He is affiliated with M.I.T. Artificial Intelligence Laboratory, and is supported by NSF, LFM, DARPA, and The Stanley Works.

Professor Steven Eppinger's research activities include projects aimed at improving product design procedures and manufacturing process control techniques. He also conducts research projects within M.I.T. Laboratory for Manufacturing and Productivity, with funding from NSF, Digital, General Motors, and LFM.

Professor Anantaram Balakrishnan is collaborating with S. Brown (Materials Science and Engineering) to develop an integrated process planning model that incorporates physical process constraints for extrusion and tube drawing. He also continues to work on planning and scheduling models for printed circuit board assembly operations, on-line schedule up-dating methods, and optimal capacity expansion models for telecommunication networks.

Operations Research and Statistics. Using statistical and probability methods. Professor Arnold Barnett has studied subjects that shape public policy, particularly in the areas of aviation safety and criminal justice. He has also done recent work on voting systems, war casualties, and the question "when is a model good enough?"

Professor Gordon Kaufman continues to focus on the exploration and exploitation of primary energy resources and on statistical and mathematical problems in resource estimation. He has also been applying his methodology to the problem of characterizing large system software failures.

In addition, Professor Roy Welsch has studied nonlinear regression for exponential family models, the use of graphics in statistical analysis, computer guided diagnostics in statistics, and new methods for variable selection in regression, and risk management in financial credit services.

Professor Dimitris Bertsimas has worked on combinatorial optimization, probability analysis of combinatorial problems, queueing theory, and queueing networks.

Professor Robert Freund has continued his research on new methods of linear programming that build upon the new algorithm developed by Narendra Karmarkar at AT&T Bell Laboratories.

Professor Thomas Magnanti has studied optimization models and algorithms for problems in communication system design, production management and distribution systems planning.

Professor Jeremy Shapiro has continued to work on a variety of applications of mathematical programming in manufacturing, logistics planning, and financial planning.

Professor James Orlin has worked on developing faster algorithms for problems in network optimization. he is interested in developing solution procedures (algorithms) that are demonstrably efficient, either in the worst case or the average case.

Information Technologies. The increasingly widespread availability of information from numerous sources both within and external to organizations and the rapid changes in information technology poses significant opportunities and challenges to management. The Information Technologies Group addresses these issues by experimenting with new technologies such as expert systems and heterogeneous databases, by examining a variety of strategic information applications, and by studying underlying organizational issues.

Professor Erik Brynjolfsson focuses his research on the economic impacts of information technology, including organizational design, decision-making authority, compensation systems, and productivity.

Professor Randall Davis continued his artificial intelligence studies of understanding and reasoning "how things work" and of the attributes of good representations of knowledge.

Professor Thomas Malone established the Center for Coordination Sciences which focuses on developing computer systems that help people work together in groups and organizations, predicting and suggesting changes in human organizational structures that accompany the use of information technology, and developing computer systems whose internal structure is based on insights gained from analyzing human organizations.

In related research, Professor Stuart Madnick has been analyzing Composite Information Systems (CIS) that facilitate applications requiring inter-organizational coordination (e.g., between supplier and buyer) and intra-organization coordination (e.g., between branches in New York and London). A prototype system, called CIS/TK, which currently integrates five disparate information systems has been developed by this group. Extensions to deal with rapidly changing semantics and identification of sources are being developed.

Professor Chris Kemerer has developed models to aid the management of software development and is developing and testing measures of software productivity. His most recent works involve estimating the impact of software complexity on software maintenance costs.

Professor Wanda Orlikowski's research concerns the relationship between information technology and organizational change. She has continued her research into the automation of systems development work, the role of electronic communication media in coordinating work, and the restructuring of organizations through information technology.

Professor Richard Wang has extended his work on the issue of "where is the data from?" in database management to address issues involved in developing Quality Data Base Management Systems (QDBMS) for delivering quality data to data consumers. Professor Wang is also organizing the first Workshop on Information Technologies and Systems (WITS) which will serve as the forum for the exchange of ideas by faculty and leading industry practitioners in the Information Systems field.

Dr. John Rockart continues his work on critical success factors, systems development, and management of data resources. He is expanding his work on executive support systems downward into the organization as Management Support Systems and is exploring the use of information technology to manage interdependent organizations of a firm.

Dr. Jeffrey Meldman continues to track developments in the legal protection of information, particularly proprietary rights in software and personal rights of privacy.

Marketing. John Little has continued his research on (a) modeling advertising effects, (b) finding the news in scanner data, (c) estimating non-linear parameters in multinomial logit models, (d) merchandising measures for a product line, and (e) non-parametric statistics for model-building in large data bases.

Glen Urban has continued his research on new-product development. One major focus (with John Hauser) has been on the development of a multi-media system to accelerate information to consumers so that we can observe and predict decision processes that normally take place over a period of months. One key application is to forecast the adoption of alternative-fuel vehicles in 1995. He has also continued his research on the advantage to being first to market. Current work concentrates on time series/cross-sectional analysis of data derived from electronic checkout records. In addition, he has published *Advanced Marketing: Phenomena, Analysis, and Decisions* (with Steven Star), a text and case book on marketing strategy. He is currently revising (with John Hauser), *Design and Marketing of New Products*, a 1980 textbook that is the market-share leader in graduate product-development subjects.

John Hauser, in addition to his responsibilities as Editor-in-Chief of *Marketing Science*, has continued his research on understanding the voice of the customer for use in new-product development. His research on this subject has led to improved methods of data collection so that firms have better information on customer wants and needs. This information, in turn, leads to more profitable products that satisfy customers. Along with Birger Wernerfelt, he has begun to investigate how measures of customer satisfaction can be used to provide incentives for firms to maximize long-term profits. In collaboration with Glen Urban, he has continued research on how consumers search for and use information when evaluating new products.

Birger Wernerfelt has continued his research on how pricing systems are developed. For example, he has explored why in the United States consumers bargain with automobile dealers but in some European countries the price is taken as posted. Similarly, in Japan, the dealer comes to the customer but in the United States the consumer comes to the dealer. These are just some of the examples of what is developing into a complex theory of shopping behavior.

William Qualls has used theories drawn from the behavioral sciences to describe and explain marketing management practices. His most recent research activity has focused on the modeling of market behavior in (a) the bundling of financial services by understanding the consumer evaluation processes, (b) modeling the effects of changes in the European financial services market, (c) modeling advertising response under difficult but common conditions, and (d) testing hypotheses about household decisions.

France LeClerc has completed two papers. A paper on the characteristics of successful consumer information programs and a paper on the choice processes for non-durable goods have been submitted. She is conducting research to understand (a) how consumers choose attributes upon which to focus, (b) how consumers react to deals in the delivery of products or services, and (c) how consumers make decisions within supermarkets.

Wujin Chu has conducted extensive research on channels of distribution. In particular, he has examined (a) different ways a channel system deals with information uncertainty, (b) mechanisms that enhance channel coordination, and (c) decisions whether to have your own sales force (vertical integration) or to sell through an independent distributor.

Behavioral and Policy Sciences (BPS)

Faculty in the Behavioral and Policy Sciences Area (BPS) bring a diverse set of social and behavioral science disciplines and methodologies to bear on a broad range of managerial and public policy issues. BPS is composed of faculty groups that focus on corporate strategy, and international management, human resources and industrial relations, technology and innovation, organization studies, law, communications, and system dynamics. These subgroups are not only linked together for administrative purposes, but reflect our vision of the interdependence of these functional areas for addressing the critical challenges facing managers and policy makers today.

One of the major changes this year was the combination of the formerly separate corporate strategy and international management groups. This integration reflects the fact that, given the globalization of markets and economic activity, corporate strategies must be conceptualized as global in scope as well. Moreover, combining the faculty from these two groups will allow us to build on and better relate firm-level strategic analysis to the School's and MIT's unique strengths in international economics and political economy. We anticipate payoffs from this integration in the years to come in both our research and teaching programs.

Area Wide Initiatives. During this year the final editing was completed on the papers and conference discussion from the BPS conference on organizational change that was held in May and June 1990. A book titled *Transforming Organizations* that contains this material will be published in October 1991 by Oxford University Press. This book contains contributions by approximately twenty BPS faculty and students and represents our effort to summarize and integrate our individual research on the broad theme of organizational change. We see the subject of organizational and social change as a theme that cuts across much of our work and one that we see growing in importance in both intellectual and professional circles. We believe our individual and collective works can play a leading role in these discussions and look forward to using the book in our teaching programs with MIT students and outside professional groups.

In 1992 BPS will celebrate its tenth anniversary as an administrative unit. In anticipation of this mark, the faculty decided to begin the process of an internal and external analysis of its strengths, weaknesses, and vision of its future. We plan to devote considerable time and energy to this task during the 1991-92 academic year. As part of the effort, we will establish a visiting committee composed of academic colleagues, industry experts with an interest in our work, and alumni of our Ph.D. program. We will report on the results of this effort along with our plans for the future in next year's Annual Report.

Organization Studies. MIT has been a leader in the field of organizational change and development since the field was born here in the 1960s. Professor Edgar Schein continued this tradition this past year with research

that focused on the role of organizational cultures that are related to different organizational and individual phenomena such as the use of information technology, leadership patterns of CEOs and other top executives, and career systems of individual managers. His work will appear in our BPS conference book *Transforming Organizations* in the research volume from the Management of the 90s project, and in revised editions of two of his well known books on Organizational Culture and Organizational Psychology.

Deborah Ancona continued her various studies of how internal and external organizational factors affect the performance of new product teams and other groups. She has examined how teams in several high technology firms manage their boundaries and negotiate for resources needed to perform effectively. In addition she examined how group diversity (or cross functional teams) affect group performance. This work contributes to the growing recognition that teamwork and effective problem solving are critical for delivering new technologies and products to the marketplace. One of her papers from this work titled "Outward Bound: Strategies for Team Survival in the Organization," won the award for the best paper published in organizational behavior in 1990 from the Organizational Behavior Division of the Academy of Management, the leading academic professional society in her field. A paper on Deborah's work is also included in *Transforming Organizations*.

Professor Robert Thomas is examining how basic choices concerning technologies are made and the political aspects of managing the development and implementation of new technology projects. Several years ago he studied intensively with ethnographic methods three new technology projects in a major aerospace firm and concluded that the course of technology development is influenced by the dynamics of power and politics within these organizations. Working with several companies in the MIT Leaders for Manufacturing Program, he then extended his analysis by studying similar projects in other companies. He is now in the final stages of drafting a major book on this process of using his National Science Foundation grant along with support from the LFM Program. He too contributed a paper from this work to the BPS *Transforming Organizations* book and has two papers on the work coming out in discipline based journals in his field, insights into how managers and workers can use the discretion available in choosing among technological alternatives to address both their own needs and those of their organization.

Professor John Van Maanen followed up the publication of his editing of a special issue of the *Journal of Contemporary Ethnography* devoted to analysis of different ways to present ethnographic research findings by organizing the papers into a book that will appear next year. In addition, Professor Van Maanen continued his ethnographic research on employees at Disneyland. This work will be extended into what promises to be a fascinating book.

Professor Lotte Bailyn is now well on her way into a major project that explores organizational responses to work/family issues. She is using follow-up data from Sloan School graduates and supplementing these individual data with studies of the broader network of spouses, peers and bosses that interact with these individuals and affect their career and family experiences. Professor Bailyn prepared a paper for *Transforming Organizations* that outlines the need for managers to bring family considerations into decisions about organizational design and human resource policies. This work is beginning to receive the attention it deserves from both the media and the broader professional community. A recent *Boston Sunday Globe Magazine*. The issue of work and family is destined to be an important issue for social policy in this decade and Professor Bailyn's research will help provide an analytical base for these discussion and policy debates. This year, Professor Bailyn was also elected a fellow of the American Psychological Association and listed in Who's Who of American Women and the World Who's Who of Women.

Several BPS faculty have been actively studying individual decision-making processes and thereby building a BPS presence in the field of behavioral decision theory.

Professor John Carroll published several papers on negotiator cognitions and their effects on behavior. In addition, Professor Carroll has begun work on the organization and management of nuclear power plants in a joint project with faculty from the Nuclear Engineering and Energy Lab. The principal goal of the project is to develop an understanding of how the organization and management of these plants affects safety performance.

Professor John Sterman has applied system dynamics modeling techniques to the study of dynamic decision-making in managerial organizations. This year he extended this work to address issues of corporate strategy and organizational learning. By integrating his system dynamics methodologies with behavioral decision

theory, Professor Sterman is forging new ground in the analysis of how managers learn and how their dynamic decisions influence the macrobehavior of firms, markets and other organizations in their environment. A paper on this work is included in *Transforming Organizations*. Professor Sterman also continues to link research and teaching by developing creative organizational simulation cases. His best known case is based on the former Peoples Express airline and has been used extensively in our Master's Program and has attracted considerable interest and attention outside of MIT as well.

Industrial Relations and Human Resource Management. MIT has a long and distinguished history as a leading source of theory and public policy analysis in the area of industrial relations and human resources. Along with colleagues in Organization Studies, faculty in this area have been at the forefront in providing the theoretical and empirical documentation to the growing recognition of the importance of effective management of human resources to the performance of individual firms and the macro economy.

Professor Lisa Lynch has been examining the economic returns to private sector training among young workers. In this work Professor Lynch further finds that minorities and women receive proportionately less training than their male and white counterparts and benefit less from the training they receive. Professor Lynch is also organizing a major international conference on the role of private sector training. A paper on this work will appear in *Transforming Organizations*. In addition, Professor Lynch is organizing a major international research conference on the role of private sector training to be held first in Cambridge in the summer of 1991 and later in England.

Professor Paul Osterman continued building on his long-standing interest in internal labor market theory by collecting and organizing a new data set that allows him to use industry level data to test alternative labor market theories. In addition, Professor Osterman directed a major study of poverty in the Boston area by conducting a large sample survey of Boston residents. The results of this survey were widely reported in the Boston media and are now being incorporated into policy making discussions in the city and state. Professor Osterman is now in the process of further analyzing these data by examining the debates around the persistence of an underclass of poor through a time of sustained economic growth.

There is a general belief that American firms and workers underinvest in training relative to our international competitors. Professor Osterman and Professor Thomas Kochan have begun a study of this hypothesis as part of a project commissioned by the American Council on Competitiveness, a national group of leaders from business, labor, and academic institutions chaired by John Young, CEO of Hewlett Packard. The paper will be published as part of a book on this topic edited by Michael Porter of the Harvard Business School.

Professor Mary Rowe continued her work on the management of diversity in the labor force, a topic that will gain increasing importance and exposure in the years between now and the turn of the century. In addition to adding to her rich data base on the practice of ombudsmen offices, Professor Rowe published several papers on the role of ombudsmen, internal communications and conflict resolution, and employee development.

Professors Robert McKersie and Thomas Kochan extended their work on new models of labor-management relations by working with The Collective Bargaining Forum, a national group of corporate chief executives and union presidents. This group published its second policy paper on this issue in 1991 and now is beginning to the lessons offered to the future of US labor policy and practice by European models of worker representation. Professors McKersie and Kochan draft the background paper for these discussions and policy papers. A paper summarizing the longstanding work of Kochan and McKersie on innovations and challenges facing industrial relations and human resource policy in the US will appear in *Transforming Organizations*.

Currently, Professor McKersie along with colleagues Richard Walton and Joel Cutcher-Gershenfeld are extending this research into the railroad, paper, and other industries and have drafted a book manuscript on this topic. This work builds on and will update the classic contribution on the behavioral theory of negotiations, *A Behavioral Theory of Labor Negotiations*, published by Walton and McKersie in 1965. In 1990, the Academy of Management feted this book by holding a symposium in honor of its 25th anniversary. Also, the 25th anniversary was celebrated by bringing out a second edition of the book by the School of Industrial and Labor Relations at Cornell University.

In addition, this year Professor McKersie accepted the post of Deputy Dean of the Sloan School. We wish Bob well in that capacity.

Professor James Rebitzer is working on theories of dual labor markets and employment contracts. He has also completed a draft review paper on the status of research on radical labor economics research and has begun a project comparing the use of contingent workers in Japan and the US. Over the course of the year he also published papers from his work on work hours and dual labor markets. This year he also worked on a project with Thomas Kochan examining the safety issues surrounding the use of contract workers in the petrochemical industry.

Professor Richard Locke is nearing completion a book that examines the interactions between industrial restructuring and industrial relations using data gathered from Italy for his dissertation. He has written several papers on this topic including one that will appear in *Transforming Organizations*, and is now planning a new round of research on the related theme of the relationship between international competitiveness and industrial restructuring using data from Germany and the US. He was awarded a Young Scholar's Fellowship from the German Marshall Fund to support his work.

Professor Thomas Kochan wrote several papers for public policy conferences on the industrial relations and human resource policy issues and is serving as a member of a National Steering Committee and the research team for a study of safety practices in the petrochemical industry. In addition Professors Kochan and Michael Useem completed editing the *Transforming Organizations* book and, along with Harry Katz at Cornell University, Professor Kochan completed work on a major revision of their textbook on collective bargaining and labor relations.

Senior Lecturer Donald Ephlin continued on our faculty this year after many years of distinguished leadership as a Vice President of the United Auto Workers. He is working closely with students and faculty in the Leaders for Manufacturing Program and has begun work on a book tracing the changes in the evolving role of union leadership in the process of transforming American industry.

Former Sloan School Dean Abraham Siegel co-authored as a member of the GMAC Commission a book on the future role of graduate management education. We are also delighted to report that Professor Siegel was awarded the Distinguished Service Award for 1990 from the Harvard Business School, the highest recognition that the school can offer to individuals who have "made a lasting contribution to management education".

Management of Technological Innovation. The effective management and use of science and technology are critical to the performance of contemporary organizations and the macro economies and society. Faculty in the Management of Technology subgroup are committed to discovering new concepts and methods for improving the ways new technologies enter organizations and are moved from the earliest stages of conception to productive uses in the marketplace and society.

Professor Thomas Allen continued his long-standing research on the careers of technical professionals and the performance of technical groups with support from the National Science Foundation. Professor Allen also continued to collect data for his study of computer aided design (CAD) on product development time. His hypothesis is that only when CAD is used to create new "social technology", i.e., to bring groups of workers together around a common set of data and references, does CAD contribute significantly to improved performance. In addition, Professor Allen and Professor Michael Scott Morton completed the editing of a book that contains summaries of the major research products of the now completed Program on Management in the 1990s.

During this past year Professor Eric von Hippel continued to study the interdependence between production tasks and the innovation process, a topic that he developed and for which he is the recognized world expert. In several published papers he extends the work in his recent book *The Sources of Innovation* by examining how technological information is shared among experts in different organizations. In addition Professor von Hippel continued his work on the role of "sticky data" in problem solving, i.e., tacit information that cannot be moved or transferred.

Professor Stephan Schrader is also exploring how technical information is shared or traded across organizational boundaries. He has now completed and published his dissertation research based on data from mini-mills in the steel industry and is now extending this work in the oil exploration industry in a joint project with Professor von Hippel. A summary of Professor Schrader's work on information trading across organizational boundaries will be included in *Transforming Organizations*. Professor Schrader also won an award for his research on informal trading of information from TIMS/ORSA, the leading professional organization of academic and industry professionals in the management science field.

Professor Michael Rappa is studying how revolutionary breakthroughs in technologies occur and are absorbed (or rejected) within organizations. Professor Rappa published several papers on this subject this year and is conducting further experiments in various industrial settings to extend his data base and further test his model. During this year he began analyzing data from a major survey he conducted to test hypotheses on how the technical literature within scientific networks affects the process of technological development.

Professor Edward Roberts completed his book titled *Entrepreneurs in High-Technology* that summarizes and draws together his long-standing research on new ventures and related entrepreneurial activity. It will be published later this year by Oxford University Press. Several papers from this work will also be published separately including one that will appear in *Transforming Organizations*.

Professor Marcie Tyre completed work on several articles based on her international study of organizational factors that influence the implementation of new process technologies. She has collected data from a large number implementation projects in several countries and finds that the speed and effectiveness of technological change is related to, among other factors, the ability of organizations to manage cross functional teams, to work with technical partners outside the organization, and to search for and absorb new information on technologies. A paper on this work will appear in *Transforming Organizations*. She also completed a study of the role of collaboration among users, vendors, and process developers in electronics firms in the development of new production technologies and has begun a new project with Visiting Professor Shmuel Ellis on the psychological principles at work in the cross boundary activities involved in the development of new process technologies. Professor Tyre was also a very active participant in the Leaders for Manufacturing Program over the course of the year.

Professor James Utterback is currently working to complete a book on the dynamics of innovation and is beginning several new projects on corporate transformations. This year Professor Utterback also published several papers on the research and development process in high-technology firms.

Strategy and International Management. While most all of our research addresses issues of strategic concern to organizations, and much of our faculty do work that has international scope, our new Strategy and International Management group serves as the home for faculty who specialize in research on these issues. The group also serves as an important connecting point for others with these interests in a specific functional area of management.

Professor Michael Scott Morton exemplifies this type of integrating role as head of the Management in the 1990s research program for the School. The Management in the 1990s program was a multi-year, \$5 million corporate-sponsored program involving a large number of our faculty. Its purpose was to study the roles played by information technologies in the strategies and processes of organizations today and in the future. This year the official Program came to a close and Professor Scott Morton published the first book based on this work titled *The Global Corporation of the 1990s*. Professor Scott Morton is also working on another book that draws out the broader implications of this research for management and with Professor Allen has completed the editing of a volume of collected research papers from the 90s Program.

Professor Michael Cusumano published a major book titled *Japan's Software Factories: A Challenge to U.S. Management* that compares organization designs and production systems for software development in Japanese and American firms. He uses the concept of the "software factory" to describe his observations of the dominant Japanese approach, and contrasts this to the "craft" model normally used to describe software development in American firms. His book has been widely acclaimed by those active in these industries and has provoked considerable thought and discussion among academics, managers and public policy representatives (such as Defense Department officials interested in software standards). Professor Cusumano has also published work

on his current project that examines the product development process in the auto industry, again drawing on his comparative research on Japan and the US. Another project underway examines the relationships between supplier firms and their customers.

Professor N. Venkatraman is continuing his empirical research on measurement issues in strategy research. His work represents one of the very few efforts to bring rigorous empirical research methodologies to bear on strategic management topics. Professor Venkatraman continued his work with Professor John Henderson at Boston University on a longitudinal research project designed to assess the value of using information technology in organizations. A paper outlining this research will appear in *Transforming Organizations*. In addition, Professor Venkatraman is nearing completion of several studies of the role that information technology plays in electronically integrating firms or business units with each other.

Professor Rebecca Henderson is studying why established firms often fail to incorporate radical or generational technical changes. She published a major paper on this subject and has designed follow-up studies in the pharmaceutical, semiconductor, and several other industries. A paper on this work will appear in *Transforming Organizations*. Professor Henderson was also a very active participant in the Leaders for Manufacturing Program this past year.

Professor Arnaldo Hax returned to BPS from his three year assignment as Deputy Dean of the Sloan School. During the year his book titled *Strategy Concept and Process: A Pragmatic Approach* was published along with several papers on models of the strategy development process. Professor Hax also began organizing faculty and students for a multi-disciplinary study of the evolution and performance of the Saturn Corporation, the new innovative division of General Motors.

Professor Donald Lessard took the lead responsibility for managing the integration of the Strategy and International Group. He should be congratulated for the progress achieved and recognized for the many hours of service he provided the School this year and in years past. Professor Lessard's research this past year focused on how firms cope with exchange rate volatility as part of his broader interest in how firms respond to environmental turbulence. He is now writing papers on this subject using data he collected via a large questionnaire study of how "expert functions," such as the corporate finance staff, interact with line executives to frame and analyze problems and options and to implement solutions.

Professor Eleanor Westney is an organizational sociologist with special expertise and interest in Japan. This past year she extended her analysis of research and development units of American firms located in Japan. She notes that understanding the Japanese labor markets is critical to the choice of strategies for these R&D units. This work is part of her longer term efforts to study the institutionalization of different organizational forms and strategies in the subsidiaries of multinational corporations. Professor Westney's work represents another example of the conceptual linkages we are exploring between technology, human resource practices, and organizational design and change. She too prepared a paper on her work for *Transforming Organizations*. She also completed editing a book with Sumantra Ghoshal of INSEAD titled *Organization Theory and the Multinational Enterprise*.

Professor Nicholas Ziegler works on the broad topic of the relationships between public policy and corporate strategy with a focus on public policy efforts to promote development and use of technology. He is currently drafting a book on this subject drawing on data from his dissertation collected in France and Germany.

Professor Michael Piore (Economics Department) holds a joint appointment in the Sloan School and participates in both the Strategy and International Group and the Industrial Relations Section. During this past year he prepared a paper on the future of American unions and a paper for the *Transforming Organizations* volume on his work on cross-firm cooperation in Italy. He is also currently developing a long range international comparative study of changes in industrial relations institutions along with other colleagues in the Industrial Relations Section.

Former Sloan School Dean William Pounds also participates in our Strategy and International Group. For the past number of years he has taught a very popular elective course on Applied Corporate Analysis and this year he plans to return to full time active teaching and research. We welcome Bill back with great enthusiasm.

Visiting Professor Maurice Segall has also taught a popular section of the Applied Corporate Analysis for the past two years. He brings to the School long rich executive experience in the retail and airline industries that greatly enriches his teaching and thesis supervision activities. He also participated in the conference that produced the *Transforming Organizations* book.

Law. Legal issues are growing in complexity and cost and therefore gaining increasing attention by corporate executives and public policy makers. One strategy for reducing litigation costs lies in improving our skills at negotiations and conflict resolution.

Professor Daniel Nyhart has been a leader in promoting improvements in negotiations through the development of computer-aided negotiations tools. This past year Professor Nyhart published extended his work on this subject by developing new tools for use in negotiations across firm boundaries in international joint activities. This is a major project that will extend over several years and involve scholars from multiple countries.

Professor Judith Lachman's research addresses another dimension of the litigation explosion by developing a life cycle of accidents which relates accident deterrence incentives to prior compensation awards and dispute settlement institutions.

Communication. Professor JoAnne Yates published several papers in her ongoing work on the evolution of communications technologies in industry. In addition, her major book on this topic titled *Control Through Communication* was published last year and continues to receive wide acclaim in reviews by organizational theorists, technology experts, and business historians. Professor Yates also began two new projects this year. The first is an historical study of how firms in the twentieth century collected, stored, and retrieved data and information. The second is a joint project with Professor Wanda Orlikowski from the School's Information Technology group that explores the mediating role of new electronic and voice mail communications technologies.

LEADERS FOR MANUFACTURING PROGRAM

The Leaders for Manufacturing (LFM) Program serves as an Institute response to numerous questions posed by US manufacturers about productivity improvement for greater global competitiveness.

The Leaders Program began as a five-year experimental educational/research collaboration between 11 major US manufacturing firms and MIT's Schools of Engineering and Management. Its overall goals are to discover, codify, and apply guiding principles for manufacturing; educate future manufacturing leaders; and develop a new cadre of manufacturing faculty. The program adopts a "total enterprise approach" to manufacturing: in bridging the traditional technology and management "cultural divide," it integrates all key functions and disciplines involved in creating, designing, making, and selling/servicing products. This "big-M manufacturing" approach includes not only the corporation, but also its customers, vendors, and suppliers, its community, and the government.

The essence of the program can be summarized as partnership, people, and principles. The *partnership* is tripartite, consisting of industry and MIT's Schools of Engineering and Management; its *people* include company leaders and practitioners, faculty, and students. The *principles* include those now guiding current best manufacturing practice and those that emerge as new paradigms. Launched in the spring of 1988 under the (continuing) co-directorship of H. Kent Bowen, Ford Professor of Engineering in the School of Engineering, and Thomas L. Magnanti, George Eastman Professor of Management Science, the Leaders Program draws on more than seven years of research and discussion among industry leaders and MIT faculty.

Graduate Training, Placement, and Support: Curricula. By experimenting and taking risks, the Leaders Program seeks to build identifiable, comprehensive manufacturing curricula that differ significantly from current models. The program draws on MIT's strengths in engineering and management to teach Leaders students the fundamentals of both technology and manufacturing management.

A key educational component is the Fellows Program: a two-year graduate experience integrating management and engineering, including a six-and-a-half-month internship at a sponsor company's plant site. Students in this segment of the program receive fellowships to gain valuable experience working on major issues of interest

to MIT and participating companies while earning two master's degrees, in management and engineering. The curriculum emphasizes teamwork, change management, learning by doing, and the integration of technology and management; it provides students with substantial opportunity to learn and experience leadership. In addition, it aims to instill within students an appreciation for continuous incremental improvement as well as groundbreaking, innovative improvement — and the total manufacturing enterprise's responsibility in producing both. Three themes comprise the LFM "educational pyramid": *leadership*, at the top, embraces all other activities and gives them focus; *integration* brings together the various supporting disciplinary building blocks — the *foundations* of knowledge, technical and nontechnical.

Graduates. The Leaders Program seeks to attract some of the nation's most capable, farsseeing young people to the challenging, multidisciplinary field of manufacturing, to educate and return them to the workforce with value added. Since its inception in 1988, the program has funded the education of approximately 180 graduate students. Since the program's inception, LFM has also fully or partially supported 70 research assistants earning master's degrees or doctorates through manufacturing-related research (*see the Longer-term basic research and Unrestricted junior faculty research sections of this report*).

Paradigm Shifts and Technological Development Interdisciplinary Research

The Leaders Program is attracting some of the best possible discipline-based faculty and company experts to conduct manufacturing-related research that will prove or disprove existing paradigms (i.e., principles) that are currently believed to govern manufacturing practice, and suggest new paradigms for further research and possible inclusion in manufacturing-related curricula. The program encourages interdisciplinary research teams and activities, with company collaboration (e.g., by using factories as real-life laboratories and as subjects for cross-company comparative studies).

The LFM research component is a multidimensional effort linking university research capabilities to relevant problems grounded in industrial needs — an effort vastly aided by the partner companies' substantial human and capital resources. The Leaders Program funds three types of research: fellows' projects at partner companies, longer-term basic research, and unrestricted junior faculty research. Together, these research opportunities involve approximately 50 Institute faculty members.

The Leaders Program held its first major symposium, *New Partnerships for Manufacturing Excellence*, in April 1991. The event offered a forum for sharing "the LFM Way" — what the program has learned during the past three years — with leaders from industry and academia, as encouragement to other universities and companies to institute or join programs similar to LFM, or re-direct existing programs. More than 400 individuals attended, representing more than 80 firms, almost 60 universities, and about 10 government organizations. Later, in June, the Leaders Program assisted with the 1991 Operations Management Workshop, bringing together faculty from many of the leading business schools and several leading practitioners from industry, and hosted a two-day conference funded by the Sloan Foundation focusing on manufacturing curricula

COMPUTER CENTER

Sloan students have round-the clock access to 62 hard disk Macs (SEs, LCs, Classics and Mac IIs) and PCs (AT&T and IBM 286 and 386 systems) in student labs. The majority of systems have 4MB of RAM, and all are networked to printers and the campus ethernet network. Students can access the IBM 4381 mainframe and both PC and Mac labs from home at speeds up to 9600 baud. A color laser printer, donated by Tektronix, is available for color prints and overheads.

There was a significant increase in computer projection in Sloan classrooms last year, and we recently purchased a portable color projection pad and color computers for this purpose.

Students estimate that 25% - 30% of Sloan classes require the use of the computer for other than word processing. Approximately 50 different software packages were used in Sloan courses over the year. The major applications continue to be word processing, financial and statistical analysis, communications and simulation. Where possible, software is purchased for both the PC and Mac platform, and faculty members allow students to use the hardware/software of their choice to complete class assignments. As a result of a grant from Microsoft, Word, Excel and Powerpoint (for Windows and Mac) were added to lab systems.

Mead Data Central's NEXIS is now available to students at Dewey Library or from home via modems. The NEXIS library contains the full text of more than 500 business, financial, news and general sources of interest to management professionals. An additional service contains analyses from leading banking, brokerage and research firms on the business prospects of companies and industries.

Although 90% of graduating master's students own their own home computers (half PCs, half Macs), the labs continue to receive heavy usage

- between classes
- for group work
- when class assignments require software not available on home systems
- for laser printing

Recent lab surveys rated the computing staff as excellent in helpfulness and knowledge. The facilities were rated fair to good. This was a significant improvement over the same survey given in late 1989.

For the first time, laptop computers were used by the Senior Executive program at Endicott House. The results were quite positive, and students (especially inexperienced users) enjoyed using the computers in their rooms. When the Senior Executive program is not in session, the laptops are loaned to faculty and staff for home or travel.

All Sloan faculty and staff members now have hard disk computers (split between Macs and PCs). By the end of the summer, all faculty and staff will have AT-class machines/Mac SEs or better. Approximately 66% of Sloan professors have either Mac IIs or 386-based computers. The school has a large number of dual diskette IBM PCs and XTs which are now being sold.

AFFIRMATIVE ACTION

The School continues to seek minorities and women to fill positions at the Sloan School. Within the faculty, the School was pleased to offer a black Visiting Associate Professor a position on the tenure track faculty as associate professor. We also granted tenure to a female member of the faculty, promoted a female assistant professor to associate professor, and have added another female assistant professor to our Economics group.

Nine percent of our Sloan Fellows were women, four percent minorities, and in the Management of Technology program, seven percent were women, four percent minorities. Our Masters program was comprised of 25% percent women, 8% minorities. Our ability to attract minorities is most difficult in the Doctoral program; this year 17% were women, 2% were minorities.

We were able to maintain the same level of fellowship support to minorities as last year, which was an increase over years prior to 1990. We continue to look for ways to improve our ability to attract individuals from under-represented minority groups.

EXTERNAL RELATIONS

Resource Development. A summary of the Sloan School's FY91 income indicates another excellent year for development efforts. The school raised a total of \$16,837,496 in cash and pledges in FY91. Of this amount, we received \$12,362,929 in cash and \$4,474,567 in additional pledges which are to be paid in the next several years. The \$12,362,929 was once again the highest cash revenue in the history of the School's development efforts. Of the cash gifts and pledge payments, we received \$5,130,792 in expendable revenue and \$7,232,137 in endowment in FY91.

<i>Current</i>	<i>FY90 Total</i>	<i>FY91 Total</i>
Unrestricted	443,776	551,844
Fellowships	189,549	128,110
Chairs	-	-
Restricted Research	2,842,035	3,100,005
Restricted-Research Sys. Dyn.	904,746	1,238,164
Research Patrons	-	-
Other	<u>70,725</u>	<u>112,669</u>
Total Current	\$4,450,821	\$5,130,792
<i>Endowment</i>		
Unrestricted	56,292	39,595
Fellowships	2,864,978	550,411
Chairs	2,217,877	1,137,131
Restricted Research	-	-
Research Patrons	-	-
Other	<u>6,650</u>	<u>5,505,000</u>
Total Endowment	\$5,145,797	\$7,232,137
Grand Total	\$9,596,618	\$12,362,929

Notable among the gifts was \$6,000,000 pledge (\$4,000,000 FY91 pledge payment) from the Epoch Foundation in Taiwan for support of the Asia Pacific Management Program. This support complements the \$2,000,000 pledge payment made by Nanyang Technological Institute in Singapore representing the second payment on a \$10,000,000 pledge over five years, to implement research initiatives, faculty support and ongoing curriculum development activities related to the School's Asia Pacific Initiatives. We anticipate that we will generate additional revenue from international sources in FY92 as the Sloan School attempts to globalize its curriculum/research activities.

We received a significant gift of \$1,500,000 from Sanwa Bank. This gift will support curriculum development and teaching innovation in the Master's Program, and is the product of the hard work of Associate Dean, Jeffrey Barks.

Next year's fundraising activities will continue to involve the expansion of our global initiatives in Asia and Europe and we expect to raise significant support for an Entrepreneurship Center.

Personnel Changes

This year as the Sloan School began a new relationship with Nanyang Technological University, a generous gift from them provided funding for four new chairs. Ravi Bhushan was appointed to one of the two NTU Career Development Professorships. Professor Bhushan has been on the Accounting faculty since 1986, studying financial information and capital markets and developing models describing firm or market behavior. Robert M. Freund was appointed to one of two NTU Senior Professorships. As a member of the Operations Research faculty since 1983, Professor Freund is not only a recognized leader in mathematical programming but he has also won the School's best teaching award. Professor Freund was also granted tenure this year. Paul M. Healy was appointed to an NTU Senior Professorship. As group head of the Accounting group, Professor Healy is a creative and productive scholar; he has been on the Sloan faculty since 1983 and was also granted tenure this year. Jiang Wang was appointed to an NTU Career Development Professorship. As a new member of the faculty this year, Professor Wang has concentrated his work on capital market theory and international finance.

Henry D. Jacoby was appointed to the William F. Pounds Professorship, a chair established through the generous gifts of the School's alumni, corporate sponsors, friends and colleagues. Professor Jacoby has been a member of the Applied Economics faculty since 1973, studying issues of policy and planning in the areas of energy, natural resources, and environmental quality.

Robert M. McKersie was appointed to the Society of Sloan Fellows Professor (formerly held by Professor Edgar H. Schein) and he was also appointed Deputy Dean for Research (replacing Professor Glen Urban). Professor McKersie has been part of the Industrial and Labor Relations faculty since 1980, and has focused his research on labor management relations with particular focus on bargaining activity.

Professor Stephen C. Graves was appointed Deputy Dean of the Faculty (replacing Professor Arnaldo C. Hax). He has been part of the Operations Management faculty since 1977, studying the design and control of manufacturing and distribution systems. He continues his role as Leaders for Manufacturing Professor.

Four faculty were granted tenure: Professor Robert Freund and Professor Paul Healy (both mentioned in the former section regarding NTU Professorships); Professor Andrew Lo, a member of the Finance faculty since 1988, received a Ph.D. from Harvard University in 1984 and is best known for his work in the random character of stock market prices, data-snooping problems in tests of financial asset pricing models, and statistical inference for continuous time models of asset prices; Professor Nancy L. Rose received a Ph.D. in Economics at MIT in 1985 and has been on the Sloan School faculty since that time where she studies the effects of government regulation on the economy.

Five faculty were promoted to Associate Professor: Professor Deborah Ancona, a member of the Organizational Studies group since 1986, who has studied group process and performance, team-context interaction, and boundary spanning. She obtained a Ph.D. from Columbia University in 1982; Professor Anantaram Balakrishnan, a member of the Operations Management since 1988, has studied large-scale and dynamic problems in manufacturing, logistics, and information systems, and received a Ph.D. from the Sloan School in 1985. Professor Kenneth A. Froot, a member of the Applied Economics faculty since 1986, after receiving a Ph.D. from the University of California and has conducted research on the behavior of asset prices and exchange rates and how changes in exchange rates effect the international flow of goods and capital; Professor David Scharfstein, a member of the Finance group since 1987, received a Ph.D. in Economics from MIT in 1986, and has studied Japanese corporate finance, product-market strategy and corporate finance; Professor N. Venkatraman, received a Ph.D. from the University of Pittsburgh in 1985 and joined the Sloan faculty, performing research in the area of corporate strategy, management planning and control systems.

New faculty in 1990-91 included Associate Professor Jeremy C. Stein, who holds a Ph.D. in Economics from MIT in 1986; Assistant Professors: Andrew W. Alford, holding a Ph.D. in Accounting from the University of Chicago in 1990; S. Lael Brainard who holds a Ph.D. in Economics from Harvard in 1989; Erik Brynjolfsson, who earned a Ph.D. in Managerial Economics from the Sloan School in 1990; Alfredo M. Kofman, who holds a Ph.D. in Economics from the University of California in 1990; William Qualls, who holds a D.B.A. in Marketing from Indiana University in 1982 and was a visitor last year. Jiang Wang holding a Ph.D. in Finance from Wharton in 1990; Alwyn Young, holding a Ph.D. in Economics from Columbia in 1990; J. Nicholas Ziegler, holding a Ph.D. in Government from Harvard in 1989 and who was a visitor last year.

The School had a number of visitors, faculty and lecturers: Peter Pin-Shan Chen from Louisiana State University; Kevin Crowston, a recent Ph.D. from the Sloan School Information Technology group; Shmuel Ellis from Tel Aviv University; Jolene Galegher from the University of Arizona; John S. Hammond, founder of Hammond and Associates and former member of the faculty at Harvard Business School; Heather A. Hazard visiting from Harvard Business School; Barbara Bund Jackson, formerly at Index Systems and on the faculty at Harvard Business School; Deborah J. Lucas from the Kellogg School at Northwestern University; Shoji Shiba from the University of Tsukuba; Bert Spector from Northeastern University; Kiran Verma from Harvard University.

Other changes at the School included Donald W. Davis from Guest of the Institute to Senior Lecturer; Peter Kempthorne from Associate Professor to Principal Research Scientist; Arthur Lewbel from Visiting Assistant Professor to Visiting Associate Professor and Amar Gupta from Principal Research Associate to Senior Research Scientist.

Four faculty were on sabbatical leave including Professors' Lotte Bailyn (Spring); Chi-Fu Huang (full year); Robert McKersie (Fall); Michael Scott Morton (full year).

Faculty on other leaves included Professors' Richard Schmalensee and Deborah G. Ancona.

Returning from leave were Professor's Ernst Berndt, John C. Cox, Gordon M. Kaufman, Thomas L. Magnanti, Garth Saloner; Roy E. Welsch; Ken Froot; D. Eleanor Westney.

It is with great sadness that we report the deaths of two Senior Lecturers who have provided invaluable service to the Sloan School for many years: Steven H. Star, who also served as Editor-in-Chief of the Sloan Management Review; and David O. Wood, who also served as Senior Research Associate at the Energy Laboratory.

Faculty visitors and lecturers who departed this year included Visiting Associate Professor Arthur Lewbel; Visiting Assistant Professor Antonio Mello; Senior Lecturer Iris Mack.

Within the Administrative Staff, the changes are as follows:

New appointments for Judith Boudreau, Program Manager for Special Executive Programs, John Hennen appointed for a short time as Financial Analyst; John L. Kenney, as Coordinator for Donor Relations; Scott McGuire as Analyst Programmer II; David A. Weber from Associate Director of the Masters Program to Director of the Masters Program; Alan F. White from Associate Dean of Executive Education to Senior Associate Dean of Executive Education; Peter P. Gil from Director of Special Executive Programs to Director of the Program for Senior Executives; Charles R. Grader from Associate Director of Executive Education and Director of the Program for Senior Executives to Associate Director, Executive Education Program and Director of the Sloan Fellows Program. Individuals who have departed are Brent Carlton, Financial Analyst and Olimpia E. Caceres, Systems Programmer.

LESTER C. THUROW

SCHOOL OF SCIENCE

This is the sixth, and last, report to the President that I have submitted as Dean of the School of Science. As I think about my six-year term as dean, I recall many highlights. I am very proud of the impressive new junior faculty members who have been appointed during my tenure. It is clear to me that their presence provides insurance that the future of the School of Science is in good hands. I am also pleased with the progress that has been made in the quality of education provided by the School, and I very much appreciate the positive attitudes and the efforts of the department heads and the faculty who have worked so hard to make this possible.

When I became dean the reputation of M.I.T. in science was outstanding both in research and educational programs. I am proud that the reputation has apparently not diminished in the past six years. I am confident that under the leadership of the central administration, the new dean, the department heads, and the laboratory directors, and with the high quality of the faculty and the students, M.I.T. will be at the top for a good many years in the future.

No person can function alone as Dean of Science at M.I.T. I have been fortunate in the past six years to have had the help of Evelyn Pérez as Assistant Dean for Personnel and Charlene Placido (for four years) and Richard Hill (for the past two years) as Assistant Dean for Finance. I also would like to thank Linnea Layton for six years of dedicated and loyal service as my secretary. Without the help of these individuals, I would have been lost. Finally, I want to acknowledge the efforts of a superb group of department heads and laboratory directors during my tenure as dean.

I am pleased to know that the position of dean will be in good hands for the next several years. Bob Birgeneau has done an outstanding job as head of the Physics Department and I am certain that he will be an equally outstanding Dean of Science.

ACADEMIC PROGRAMS

There were 718 undergraduates in the School of Science during the past academic year, a slight decrease from the previous year. The number of minority students at the undergraduate level changed as follows:

Blacks	Increased from 25 to 26 (4% increase)
Hispanics	Increased from 24 to 30 (25% increase)
Native Americans	Increased from 1 to 2 (100% increase)
Asian Americans	Decreased from 139 to 137 (1.4 % decrease)

The female undergraduate population decreased from 292 to 272 (6.8%). Twenty-two percent of the Institute's upperclass undergraduates were enrolled in the School of Science.

Graduate enrollments in science increased from 1,068 to 1,069. The total enrollment represents 22 percent of the graduate population at MIT. The number of minority students at the graduate level changed as follows:

Blacks	Decreased from 11 to 8 (27% decrease)
Hispanics	Decreased from 12 to 10 (17% decrease)
Native Americans	Decreased from 2 to 0 (100% decrease)
Asian Americans	Decreased from 28 to 27 (3.6% decrease)

The number of female graduate students decreased from 259 to 256 (1%).

There were 260 faculty members in the School this past year. This represents a slight decrease from the previous year. The undergraduate student-to-faculty ratio was 3 to 1, and the graduate student-to-faculty ratio was 4 to 1.

RESEARCH VOLUME

The FY'91 volume of research was approximately \$100 million.

GENE M. BROWN

Department of Biology

INTRODUCTION

The Biology Department currently has 60 faculty members of whom 16 are located in the Whitehead Institute, 10 are located in the Center for Cancer Research, 4 are joint appointees with the Department of Brain and Cognitive Sciences and 2 are joint with Chemistry. Three of the faculty are Nobel laureates, 17 are members of the National Academy of Sciences and 8 are investigators of the Howard Hughes Medical Institute. The Department has a very strong international reputation in research and teaching and has been a leading contributor to the development and application of molecular biology. Those research groups not located in the Whitehead Institute or Cancer Center will be moving to a new Biology building which recently began construction and is expected to be occupied late in 1993.

EDUCATIONAL ACTIVITIES

Undergraduate Program

In the past year, the maximum number of undergraduates registered as Biology majors was 275. Of these, 96 received the degree of Bachelor of Sciences in Biology: 78 in the regular Course VII Program, 18 in the VII-A Program. The recipient of the John L. Asinari Award for outstanding research by undergraduates in Biology for 1990-1991 was F. Scott Keiff, for work done in Professor Gerald Fink's laboratory. Due to the outstanding quality of research papers submitted for the Asinari Award this year, there were also three runners-up: Sue Lee (Prof. Krieger's laboratory), Michael Su (Prof. Eisen's laboratory), and Wayne Wu (Prof. Lippard's laboratory).

Fifty-six percent of our majors are women and 4% are underrepresented minorities.

After extensive discussions between the Biology Department, the Committee on the Undergraduate Program and the Committee on the Science Requirement and among the Institute faculty, the faculty voted to replace one of the current Science Distribution requirements by a General Institute Requirement in Biology, effective with the incoming class of fall 1993. The Biology department enthusiastically welcomes this development and is working to develop novel courses to satisfy this requirement. We feel that this will be a valuable addition to the education of all MIT undergraduates and that it sensibly reflects the increasing impact of modern biology on all our lives and the intellectual value of molecular biology. This change in Institute requirements and the new courses which we will develop will also allow us to rationalize our departmental curriculum. These changes will increase the department's teaching load significantly and present us with new challenges but we feel that both the Institute's and the department's curriculum will be improved thereby. The highly successful Project Laboratories continue to be a cardinal feature of our undergraduate training, aided in part by welcome support from a grant by the Howard Hughes Medical Institute, and numerous students conduct UROP research in department laboratories.

Graduate Program

The Department's Graduate Program continues to be one of the most highly rated in the country. During the period from July 1, 1990 to June 30, 1991, 24 Ph.D. degrees and 1 Master's degree were awarded in the Department; 3 Ph.D. degrees were awarded in the Joint Program in Biological Oceanography with the Woods Hole Oceanographic Institute (WHOI). The maximum number of Ph.D. candidates registered in the Department in 1990-1991 was 185, with another 20 in the Joint Program. The entering class in 1990, including 3 in the Joint Program, was 36. The class arriving in September, 1991 will number 35, including 5 WHOI students.

Slightly over 41% of our graduate students are women and 0.01% are minorities. The graduate program is supported by several training grants from NIH, by small amounts of industrial and foundation support, and from research grants. Support of graduate students threatens to become an issue as funding agencies place caps on the tuition they will pay so that we are presented with a major shortfall in tuition support.

RESEARCH

The research activities of the Department are in the areas of cellular and molecular biology, genetics, biochemistry and biophysics, plant and developmental biology, immunology, and neurobiology. Research activities are described in the annual publication, *Department of Biology, M.I.T.: Annual Report*, available in the Biology Headquarters Office (56-511). The FY91 total direct cost of research in the department (including the Cancer Center and the Whitehead Institute) was \$26.75m (\$10.7m of that was in the Whitehead). MIT overhead on the funding in the department and the Cancer Center was \$9.23m. At a time of difficult research funding, the department has maintained its level of federal support. In addition to faculty and students, 275 Postdoctoral Associates and Fellows perform research in the various laboratories of the department.

PERSONNEL

Professor Donald Rio was promoted to Associate Professor effective July 1, 1991, and Professors Leonard Guarente, Monty Krieger and Richard Mulligan were promoted to Full Professor effective July 1, 1991. Professor Richard Young was awarded tenure effective July 1, 1991.

Prof. Chris Kaiser joined the Department as Assistant Professor of Biology in April 1991. Dr. Kaiser received the A.B. (magna cum laude) in Biochemistry from Harvard University in 1980 and the Ph.D. in Biology from MIT in 1987. Since 1987 he has been a Postdoctoral Fellow in the laboratory of Professor R. Schekman in the Department of Biochemistry at the University of California, Berkeley. Dr. Kaiser received a 1990 Markey Scholar Award. His research interests focus on the cell biology and biochemistry of yeast.

Professor Hazel Sive accepted a position as Assistant Professor of Biology and Associate Member of the Whitehead Institute for Biomedical Research; she began her position May 1, 1991. Professor Sive is a developmental biologist who focuses on the early development of vertebrate embryos. She obtained her B.Sc. from University of Witwatersrand in 1979 and the Ph.D. from Rockefeller University in 1986. She was a Postdoctoral Fellow in the laboratory of Professor Harold Weintraub at the Fred Hutchinson Cancer Center in Seattle.

Finally, Dr. Tania Baker, a DNA biochemist, who obtained her Ph.D. in 1988 in the laboratory of Professor Arthur Kornberg at Stanford and is currently doing postdoctoral research in Dr. Mizuuchi's laboratory at the National Institutes of Health, accepted a position as Assistant professor in the department. She will join the faculty during the next academic year.

Regrettably, one faculty member, Professor David Raulet, an immunologist, left the department to take a position at UC Berkeley. We will miss him but wish him well in his new position.

We were much saddened by the death of Professor Salvador Luria in February, 1991. Professor Luria was one of the leaders of the department during its period of growth, the founder of the Center for Cancer Research, an Institute Professor and a great friend and colleague of all of us.

The department is committed to increasing the representation of women and underrepresented minorities among our faculty. We note with pride that 4 out of our last 9 appointments were women (2 of the 4 appointments made last year). We have an offer outstanding to an excellent young scientist working on protein folding who is an Afro-American and we will continue our efforts to recruit him.

Honors and Awards to the Faculty

It is a pleasure to report the following honors and awards received by various faculty members during the past year:

Professor H. Robert Horvitz was elected to the National Academy of Sciences and to the Genetics Society of America Board of Directors.

Professor Carl Pabo received the Protein Society's 1991 Young Investigator Award (sponsored by the DuPont Merck Pharmaceutical Company).

Professor David Page received the 1990 Serrano Award from the American Society of Andrology.

Professor Uttam RajBhandary was elected to American Academy of Arts and Sciences.

Professor Donald Rio was awarded the Robert A. Swanson Professorship in the Life Sciences.

Professor Robert Sauer was named as the Whitehead Professor of Biology.

Professor Phillip Sharp was elected to the American Philosophical Society and to the Institute of Medicine of the NAS, and received The Dickson Prize from the University of Pittsburgh.

Professors Lisa Steiner and Joanne Stubbe were elected Fellows of the American Academy of Arts and Sciences.

OTHER

The department's leadership will change with the new academic year when Phillip Sharp becomes Head of the Department and Richard Hynes becomes Director of the Center for Cancer Research. With the start of the new building and the adoption of the Biology requirement the department is embarking on an exciting new period.

RICHARD O. HYNES

Department of Chemistry

The Department of Chemistry continues to be one of the leading academic centers of chemical science in the United States, with educational and research programs covering all the major areas of chemistry. In the 1990/91 academic year, there were 35 faculty, 80 postdoctoral researchers, 250 graduate students, 100 undergraduate majors, and 50 staff members actively involved in departmental programs. Research support continues to be strong, with approximately \$13 million during the last year. The departmental educational programs are also strong. In the following sections, some of the important departmental activities of the past year are presented.

ACTIVITIES OF THE DEPARTMENT

Professor Mark S. Wrighton, Department Head since 1987, was named Provost of MIT on October 16th by President Charles M. Vest. The Provost is the university's chief academic officer. Professor Wrighton succeeds John M. Deutch who had served as Provost for the past five years. **Professor Robert J. Silbey** has been named head of the department by Dean of Science, Gene M. Brown.

A two-day symposium, co-sponsored by the Chemistry Department and the MIT Industrial Liaison Program entitled, "Chemistry of Interfaces" was held May 2 and 3, 1991 in the Kresge Auditorium. This meeting highlighted the advances in synthesis, reactivity, structure and growth, and theory in this important area of chemistry and technology.

The Chemistry Visiting Committee met on November 13 & 14, 1990. Those in attendance were Dr. Jerry McAfee, Professor John I. Brauman, Dr. Richard L. Hinman, Dr. Theodore M. Bednarski, Professor Joseph S. Francisco, Mrs. Margaret Coleman Haas, Dr. Jerry R. Mohrig, Dr. H. E. Simmons, Ms. Sarah A. L. Tabler, Dr. Kathleen C. Taylor, Dr. Sharon L. Haynie, Mr. J. Kenneth Jamieson, and Dr. Arthur Obermayer.

The Women in Chemistry Group continues to be highly successful. The main purpose of the group is to encourage women of the department to interact and to get to know one another. This group has established a network for women at MIT to come in contact with other women in chemistry. While Dr. Mary Good, Sr. Vice President Technology, Allied-Signal Corp. and Chair, National Science Board was at MIT as a distinguished ADL lecturer, the Women in Chemistry hosted a luncheon for her. In addition, Dr. Patricia Morris and Dr. Patricia Watson of the DuPont Corporation Research Laboratory came to MIT to discuss issues of women in industrial science with the Women in Chemistry Group.

Our graduate and undergraduate students continue to be active in the High School and Elementary School Chemistry Outreach Program. The High School Outreach Program under the leadership of Professor Peter T. Lansbury, has been brought to more than 50 high schools in the New England area. The undergraduate chemistry majors undertook the development of a "Magic Show" in hopes of stimulating stronger science programs in local elementary schools a couple of years ago, and this proves to be a continued success.

On January 23 and 24 MIT held a special symposium to honor Henry C. McBay as the first Martin Luther King, Jr. 1991 Visiting Scholar. Dr. McBay is Professor of Chemistry, Emeritus, Morehouse College. Dr. McBay's contributions to the education of African Americans, particularly in chemistry and allied areas, illustrate the importance of individual effort. Like Martin Luther King, Jr. himself, Dr. McBay is a role model and has joined the ranks of the leaders in education of African Americans.

CHEMICAL HYGIENE PLAN

It is the policy of MIT to provide a safe and healthy workplace in compliance with the Occupational Safety and Health Act of 1970. The Chemistry Department works diligently toward complying with this policy. New employees must attend a safety seminar and review educational materials, including the new Chemical Hygiene Plan. There is a Chemical Hygiene Committee that works closely with MIT's

Safety Office and assists the chairman with the development and implementation of this plan. As a result of this effort, the Chemistry Department was chosen to be the 1991 recipient of the Division of Chemical Safety's College Safety Award. The department owes a debt of gratitude to **Professor Rick Danheiser** who worked so diligently to accomplish this.

IN MEMORIAM

Howard O. McMahon, PhD '41, former president of Arthur D. Little, Inc. and Chairman of Helix Technology Corporation, died of heart disease in early August. McMahon was honored by over 70 associates and friends at MIT in June, 1988 at the establishment of a research endowment for physical chemistry named in his honor. Many alumni have made contributions to the fund since its founding.

Edmund Lee Gamble, PhD '34, professor emeritus, died on November 28 in Hyannis, MA. He joined the chemistry faculty in 1934 after completing his doctorate. He was well known for the style and enthusiasm he conveyed to many years of freshman chemistry students.

PERSONNEL

Professor Robert Alberty was elected as a member of the Council of the American Academy of Arts & Sciences. Professor Alberty retires July 1, 1991.

Professor Mounji Bawendi joined the faculty as Assistant Professor in 1990. Professor Bawendi was a postdoctoral fellow at AT&T Bell Laboratories at Murray Hill. He was educated at Harvard (AB, chemistry in 1982) and the University of Chicago (PhD, physical chemistry in 1988). He is one of 11 recipients nationwide of a Camille and Henry Dreyfus Foundation New Faculty Award. He also recently received the prestigious Presidential Young Investigator's Award from the National Science Foundation.

Dr. George Büchi, Camille Dreyfus Professor of Chemistry, is the 1991 recipient of the James R. Killian Jr. Faculty Achievement Award. He delivered the award lecture "On the Sunny Side of Organic Chemistry" on April 3rd. Professor George Büchi retires July 1, 1991.

Professor John M. Deutch, widely known as a scientist, government official and former MIT provost, has been named Institute Professor - a title reserved for scholars of special distinction. Even as he steps down as the Institute's provost and returns to the department as Institute Professor, John Deutch will continue to play a high level role foreign to most physical chemists. In July, President Bush reformulated his Foreign Intelligence Advisory Board and appointed Deutch to a two-year term.

Professor Robert W. Field was the recipient of the 1990 Ellis Lippincott Award jointly sponsored by the Optical Society of America, the Society of Applied Spectroscopy and the Coblenz Society. The award recognizes significant contributions to vibrational spectroscopy and was presented on November 7th at the OSA Annual Meeting in Boston.

Professor Frederick Greene was the recipient of the School of Science Teaching Award.

Professor Alexander M. Klibanov was selected as the 1991 recipient of the Marvin J. Johnson Award of the Biochemical Technology Division of the American Chemical Society.

Professor Peter Lansbury received a 1991 Camille and Henry Dreyfus Teacher Scholar Award and also a 1991 Alfred P. Sloan Research Fellowship.

Professor Stephen J. Lippard presented the second annual Aquanautics Lecture at the University of California at Davis on May 31st.

Professor Satoru Masamune was appointed as Arthur C. Cope Professor of Chemistry, effective April 1, 1991.

Professor Mario J. Molina and Charles E. Kolb organized and chaired the 1991 Atmospheric Chemistry Gordon Research Conference on June 16-21.

Professor William Orme-Johnson was invited to be the Visiting Professor of Chemistry during the Spring 1991 semester and to participate in the "Frontiers in Chemical Research" lecture program at Texas A&M University for April 29-May 2, 1991. He joins Professors Mark Wrighton and Julius Rebek, Jr. who also received this honor. He was also a featured speaker at the dedication of the Stanford Positron Electron Accelerator Ring (SPEAR) at the Stanford Synchrotron Radiation Lab on October 4th.

Professor Julius Rebek, Jr. was appointed as the Camille Dreyfus Professor of Chemistry, effective July 1, 1991. Professor Rebek was also named one of the Arthur C. Cope Scholars for 1991. This award, named in honor of the department's former chairman, recognizes outstanding research in organic chemistry. In addition, **Professor Julius T. Rebek, Jr.** had his work on self-replicating molecules featured in an October 30th New York Times article entitled "Chemists Make Molecules with Hint of Life". Professor Rebek also presented the second annual Myron Bender lectures at Northwestern University last June.

President George Bush presented the National Medal of Science to former faculty member **John D. Roberts** at a White House ceremony in mid-November.

Professor Richard R. Schrock was presented with the 1990 Harrison Howe Award by the Rochester Section of the American Chemical Society on October 17th. Prof. Schrock was honored for his work on the synthesis of transition-metal complexes containing carbon-metal bonds and their role in the catalysis of reactions such as olefin and acetylene metathesis.

Professor Robert J. Silbey was elected as a member of the American Academy of Arts & Sciences. He also received The Everett Moore Baker Memorial Award for Excellence in Undergraduate Teaching.

Professor JoAnne Stubbe was also elected as a member of the American Academy of Arts & Sciences. She also received the MIT Graduate Student Council Teaching Award.

Professor Jamie Williamson has joined the department as an assistant professor. His most recent position was at the University of Colorado as a post-doctoral associate in the lab of 1989 Nobel Laureate Thomas Cech, where he studied telomere structure. Prior to that, he was a graduate student in organic chemistry at Stanford University. He was appointed the holder of the Pfizer-Laubach Career Development Assistant Professorship, effective July 1, 1991. He also received the 1991 Searle Scholars Award from the Chicago Community Trust.

Professor Hans-Conrad zur Loye was selected as the recipient of the DuPont Young Faculty Grant which the Chemistry Department recently received.

Ms. Cynthia D. LuBien, Ph.D. '82 has been promoted to the position of Manager of Corporate Relations.

GRADUATE STUDENTS

In the Fall of 1990 the Department admitted 44 students to the graduate program. The Department awarded 3 M.S. degrees and 39 PhD degrees this year. Many graduate students received fellowships for the academic year 1990-91. Four students received AT&T Fellowships; five students received Howard Hughes Fellowships; sixteen students were awarded NSF Fellowships. Three new fellowships were

established this year. They were the 3M Fellowship awarded to Harold Fox; ARCO Chemistry Outreach Fellowship awarded to Jon Come and Michael Keck; and the MILAS Fellowship awarded to Scott Johnson.

UNDERGRADUATE STUDENTS

The Department awarded several chemistry undergraduates with the following awards: Hou Chen and Rebecca B. Scarr received Alpha Chi Sigma Awards for achievement in Research, scholarship and service to the Department; Gerald R. Cain and Susan E. Jackson received the Merck Index Awards for outstanding scholarship; and Michael D. Beachy received the Undergraduate Research Award for outstanding contributions in Chemistry research by an undergraduate.

Other awards which students received are the following: James P. Donahue received the American Institute of Chemists Foundation Student Award; Rebecca Scarr received the Association of MIT Alumnae Award presented by the Association of MIT Alumnae to outstanding women who have demonstrated the highest level of academic excellence through their coursework and related professional activities at MIT. Three undergraduate members of the Department were recipients of National Science Foundation Fellowships for September 1991: Gerald Cain, Hou Chen, and James P. Donahue. Helen Banava, Michael D. Beachy, Gerald R. Cain, James P. Donahue, Susan E. Jackson, Gary L. Quick, and Rebecca Scarr were nominees for Associate membership to Sigma XI - The Scientific Research Society of North America; Gerald Cain, James Donahue, Susan Jackson, and Rebecca Scarr were initiated into the Phi Beta Kappa (XI Chapter).

DISTINGUISHED VISITORS

The Chemistry Department was privileged to host six distinguished scientists in endowed lectureships during the past academic year. Professor Jack E. Baldwin, University of Oxford, was the Karl Pfister Visiting Professor in Organic Chemistry in October, 1990. Dr. Mary Good, Sr. Vice President Technology, Allied-Signal Corp and Chair, National Science Board was an A.D. Little Lecturer in December, 1990. Professor R. J. P. Williams, Oxford University, was an A.D. Little Lecturer in Inorganic Chemistry in February, 1991. Professor Roger Y. Tsien, University of California at San Diego, was the T.Y. Shen Visiting Professor in March, 1991. Professor John Roberts, California Institute of Technology, was the George Büchi Lecturer in April, 1991. Professor John Brauman, Stanford University, was the A.D. Little Lecturer in Physical Chemistry in April, 1991.

ROBERT J. SILBEY

Department of Earth, Atmospheric, and Planetary Sciences

INTRODUCTION

The Department of Earth, Atmospheric, and Planetary Sciences (EAPS) is one of the broadest and best integrated earth science organizations in the world. Its research mission is to investigate the workings of the Earth's interior, oceans, and atmosphere, as well as the other planets of the solar system, and to understand the dynamical relationships that govern weather, climate, and the Earth's long-term geological evolution. Its educational mission is to train the best students for careers in earth science research and to encourage them to attack some of the most fundamental problems confronting a globalized society. These problems range from the search for new natural resources to the effects of greenhouse-gas emissions on the global climate.

EAPS comprises 38 faculty, 77 research staff, 30 support staff, 172 graduate students, and 27 undergraduate students. All of the faculty are engaged in both research and teaching. Nearly all of the graduate students (94%) are working towards a Ph.D. degree. Although the interdisciplinary nature of the EAPS activities make divisions by field somewhat arbitrary, the research and teaching is organized in terms of five disciplinary groups: Geology and Geochemistry, Geophysics, Planetary Science, Oceanography, and Meteorology.

Several organizational structures overlay these disciplinary groupings. The Department administers the Earth Resources Laboratory (ERL), the Center for Meteorology and Physical Oceanography (CMPO), and the Center for Global Change Science (CGCS). In addition, it is a major participant in the Center for Space Research (CSR) and the Joint Program between MIT and the Woods Hole Oceanographic Institution (WHOI).

FACULTY AND RESEARCH STAFF

Two new faculty have been appointed, Sam Bowring to untenured Associate Professor and Timothy Dowling to Assistant Professor. Professor Bowring is a U-Pb geochronologist whose research links two traditionally strong areas within EAPS, laboratory geochemistry and field geology. He is well known for his work in Proterozoic and Archean terrains, including his recent discovery and characterization of the Earth's oldest rocks (3.962×10^9 years) in the Slave province of Canada. Professor Dowling is a planetary scientist who did his thesis research on the hydrodynamics of the large, long-lived vortices in Jupiter's atmosphere, in particular the formation and stability of the Great Red Spot.

On July 1, 1991, Jack Wisdom and Timothy Grove were promoted to Professor, Daniel Rothman to Associate Professor with tenure, and Richard Binzel and John Grotzinger to untenured Associate Professor. Dr. Heidi Hammel was promoted to Principal Research Scientist. Professor Marcia K. McNutt was awarded the Griswold Professorship.

Honors

Professor Emeritus Edward N. Lorenz, a meteorologist renowned for his work in the dynamics of atmospheric circulation and the first to recognize what is now called chaotic behavior in the mathematical modeling of weather systems, won the 1991 Kyoto Prize for basic sciences in the field of Earth and Planetary Sciences. He is the fourth member of the MIT faculty to become a Kyoto Laureate. Professor Carl Wunsch was awarded the Maurice Ewing Medal of the American Geophysical Union. Professor Thomas A. Herring received the Macelwane Medal from the American Geophysical Union. Professor Richard P. Binzel received a Fullam/Dudley Award for his project "Small Main-Belt Asteroid Spectroscopic Survey: A Search for the Missing Pieces." Professor Leigh H. Royden was selected for a Faculty Award for Woman Scientists by the National Science Foundation. Professor Roger Burns was awarded a Guggenheim Fellowship. Dr. Heidi B. Hammel received the NASA Group Achievement Award for her participation on the Voyager Imaging Team during the Voyager encounter with Neptune. Professor Timothy Dowling received the Jephtha H. and Emily V. Wade Award.

EDUCATION

The Department's revised undergraduate curriculum was implemented this past academic year. The most important change involved the establishment of a series of core curriculum courses, one each in Geology and Geochemistry, Geophysics, Planetary Science, Meteorology and Physical Oceanography, and a new course in continuum mechanics. Success of the core subjects was indicated by large enrollments and favorable student evaluations.

The graduate curriculum is in the process of being extensively revised by the faculty in the various disciplines. The Center for Meteorology and Physical Oceanography recently completed a comprehensive revamping of their core graduate program to recognize new advances in such areas as atmospheric chemistry, tropical meteorology, and climate modeling. New faculty appointments in Geology and Geochemistry have prompted the redesign of field subject offerings and the role these subjects play in training students for professional or academic careers. New course offerings included a subject designed by Professors Leigh Royden and Clark Burchfiel on plate tectonics and continental deformation. Science distribution subject

12.400, the Solar System, was completely redesigned by Professor Richard P. Binzel: using the latest spacecraft results, students are introduced to planetary science through applications of physics, geology, meteorology, and chemistry.

CENTER FOR GLOBAL CHANGE SCIENCE

The Center for Global Change Science (CGCS) was established in 1989 to address scientific problems related to large-scale, long-term environmental changes. The interdisciplinary Center involves both research and education, and builds on established programs in meteorology, oceanography, hydrology, and satellite remote sensing carried out in the Schools of Science and Engineering at MIT. CGCS is directed by Professor Ronald G. Prinn of EAPS; its Associate Director is Professor Rafael L. Bras of the Department of Civil Engineering. The goal of the Center is to sustain a program of basic scientific research focused on the fundamental processes in the global climate machine, with the specific objective of improving the prediction of anthropogenic environmental changes. During the past year, CGCS has collaborated with MIT's Center for Energy Policy Research to develop a Joint Program on the Science and Policy of Global Change. The purpose of this major new initiative, which will be sponsored by industry, government, and private foundations, is to provide a more objective basis for climate change decision making through effective coupling of research on climate change prediction, climate change impact assessment, and climate change response strategy.

CURRENT RESEARCH

Meteorology

In the climate system does the atmosphere control the ocean or vice versa? Studies of global sea surface temperature from ships' reports and global air temperature from microwave sounding units on satellites by Professor Reginald Newell and graduate student Zhongxiang Wu show that, in the tropics, sea temperature changes precede air temperature changes by several months, while over the Gulf Stream and Kuroshio, the air is ahead of the ocean by about one month. Patterns of wind stress and evaporation are also being studied. In the tropics, eastern Pacific sea temperature changes are associated with a global equatorial belt of air changes.

Professor Prinn and his colleagues in the Global Atmospheric Gases Experiment (GAGE) have combined GAGE global measurements from 1978 to 1990 of the industrial compound 1,1,1-trichloroethane with estimates of its industrial emissions to deduce for the first time the rate of change of the concentration of the atmospheric hydroxyl radical that reacts with and destroys 1,1,1-trichloroethane. They deduce a surprising trend of an increase in hydroxyl radicals of 1.0 ± 0.6 percent per year. Because this radical is the principal atmospheric oxidant, this positive trend has major implications for global atmospheric chemistry and may serve to explain the decreasing trend in atmospheric methane which, like 1,1,1-trichloroethane, is destroyed mainly by reaction with hydroxyl radicals.

Professor Mario Molina and his students are currently investigating the chemistry of ice-like particles, which serve as models for polar stratospheric clouds. They have made progress in elucidating the mechanism of these cloud-induced reactions that release active chlorine in the stratosphere. Furthermore, they have successfully developed a technique to study gas phase chemical reactions at temperatures as low as those prevailing in the polar stratosphere.

Dr. Luisa Molina has been developing a laboratory technique to assess the atmospheric stability of various commercial perfluorinated organic compounds. The technique involves measuring with Fourier-transform infrared spectroscopy the chemical reactivity of these compounds towards species such as hydroxyl radicals and electronically excited oxygen atoms. Several of the compounds under study are stable enough to survive many hundreds of years in the atmosphere.

Based on the observed sensitivity of lightning activity to conditional instability in the tropics and the wet bulb potential temperature of boundary layer air, Professor Earle Williams has proposed the use of ionospheric potential as a diagnostic for global change. Radar measurements of precipitation and ground strike lightning activity over an area of 40,000 km² near Darwin, Australia (12° S) are being used to study the local diurnal variation of electrical and meteorological parameters to determine the dominant cause of the negatively-charged Earth.

Professor Kerry Emanuel implemented his new representation of cumulus convection in the numerical weather forecast model operated by the European Centre for Medium Range Weather Forecasts. The scheme appears to work quite well. He also organized and ran a workshop on cumulus parameterization. Much of his time during the latter half of the year was spent in preparing for his field experiment on tropical cyclogenesis, to take place in the summer of 1991. In addition, he continues actively to promote pilotless aircraft as ideal atmospheric measurement platforms.

Professor Peter Stone and his co-workers have been using numerical models to study the interaction between large-scale atmospheric eddies and temperature structure. They find that temperature lapse rates and meridional temperature gradients are very strongly coupled in mid-latitudes. This result will make it possible to improve the realism of many standard climate models without increasing their computational requirements.

Professor Richard Lindzen is studying aspects of dynamic meteorology and climatology ranging from the basic mechanism of shear instability to the reasons for the 100,000-year cycles in glaciation. Current work includes attempts to explain why the global response to increasing greenhouse gases has been so small, why the atmospheres of the outer planets are banded, and what determines the equator to pole temperature difference. He is also working on optimizing the resolution of both numerical models and observing systems and on what determines the intensity of the general circulation and the poleward heat flux. He was co-editor of a book that appeared this year: *The Atmosphere—A Challenge: The Science of Jule Gregory Charney*.

Professor Alan Plumb and his students are investigating several aspects of dynamics and transport processes in the stratosphere. In collaboration with Dr. Lorenzo Polvani (Columbia University) they have used a very high resolution model to elucidate the dynamics of the polar vortex and its interaction with breaking large-scale waves. The same technique is now being applied to study the dynamical behavior of synoptic eddies in the troposphere. Professor Plumb and Dr. Malcolm Ko (Atmospheric and Environmental Research, Inc.) have combined theoretical and modeling approaches to understand the observed simple correlations between mixing ratios of long-lived stratospheric trace species, in the process developing a simple technique to deduce the lifetime of these species from limited data.

Professor Randall Dole and his students have continued their observational and modeling studies of major low frequency phenomena in the atmosphere. Their results indicate that in winter internal dynamical processes are of predominant importance in the generation and maintenance of major persistent surface temperature anomalies, whereas in summer, both internal dynamics and feedbacks involving anomalous local surface conditions are likely to play significant roles. In addition, Professor Dole and a student have developed the first climatology of small scale cyclones over the North American region and have suggested potential mechanisms to account for the observed regional variations in small scale cyclogenesis.

Oceanography

Professor Carl Wunsch and his group have shown that they can consistently map global scale seasurface variability using combinations of altimetric satellite data and ordinary tide gauge data. Explicit error bars are obtained on the results. The estimates have been shown to be coherent with large-scale meteorological forcing, particularly the wind-curl.

Professor Glenn R. Flierl and his students are investigating the evolution of strong eddies and jets in oceans and atmospheres. He and Dr. Stephen Meacham have developed simplified models for the Gulf Stream structure and examined the propagation and growth rates for meanders on the jet. Nonlinear calculations, both analytical and numerical, indicate that waves can grow to break off isolated "rings" or can equilibrate in sinuous meanders. These results will be compared with the data from the observational part of the SYNOP program. The impact of this meandering on biota is also being investigated with simple models. Studies of eddies include the generation by flow over topography and the interaction with the continental shelf. Finally, he and collaborators are examining the influence of vertical and horizontal shear and of the radiation of planetary waves on strong eddies such as Jupiter's Red Spot.

Professor Paola Malanotte-Rizzoli and her group have continued the studies on the assimilation of different types of data into models of the ocean circulation. Three efforts are underway: (1) assimilation of Geosat (altimeter) data into a model of the Northern Atlantic circulation; (2) assimilation of system data from localized clusters collected during the SYNOP experiment into a model of the Gulf Stream; and (3) assimilation of hydrographic data into a model of the Mediterranean circulation. The results show that localized datasets can be quite effective in reconstructing the circulation in the regions or vertical layers where no observations are available. As a second research project she has found that some of the predictions of her theory for long-lived atmospheric anomalies are well reproduced in the observations.

Professor Edward Boyle has completed the first global survey of the distribution of the nutrient-analogue cadmium in the ocean during the last glacial maximum 18,000 years ago. He finds that the upper waters of the North Atlantic and Indian Oceans are nutrient-depleted compared to the modern ocean, and that the deep waters of the North Atlantic are more nutrient-enriched. He and post-doctoral fellow Rob Sherrell have initiated a study of the anthropogenic and cosmogenic trace element fluxes at the summit of the Greenland Ice sheet, and he and graduate student Yair Rosenthal have investigated the role of fluoride in foraminifera as a potential paleoceanographic tracer. Together with senior thesis student Julian Sachs and graduate student Deborah Colodner, he has investigated the environmental geochemistry of rhenium.

Professor John Edmond participated in the first opening of the Soviet Union to fieldworkers from the West. He was involved in sampling trips to Lake Baikal, to the Aral sea drainage in the Pamir and Hindu Kush, and to the northern Black Sea and all the rivers draining into it from Soviet territory. There will be a large expedition to the upper Lena in the Soviet Far East this summer. In April of 1991 Professor Edmond and his students participated in an ALVIN expedition to the East Pacific Rise at 9°N. They found evidence for very recent eruptions; e.g., "cooked" animals on the lava surfaces. Fluid temperatures as high as 400° C were observed. The fluids had salinities in only one percent of seawater and must have resulted from phase separation in the subsurface. This ridge segment is the most hydrothermally active yet observed. In

addition, Professor Edmond's first investigations of geochemical cycles of the platinum group elements are very successful. The elements show great diversity of behavior and cannot be considered as a group at all.

Geology and Geochemistry

Professor John Grotzinger and his students are continuing research involving the examination of the elastic strength of the Proterozoic continental lithosphere, driving mechanisms of the Milankovitch-band cyclicity on ancient shallow-water carbonate platforms, the carbonate saturation of Precambrian seawater and its implications for atmospheric $p\text{CO}_2$, and the interaction between tectonics and sedimentation in Tertiary extensional basins and the role of antithetic normal faulting. Results so far suggest that the average early Proterozoic continental lithosphere may have been as weak as the least rigid Phanerozoic continental lithosphere, suggesting that heat flow may have been higher through the continents than previously suspected. Concerning carbonate platform cyclicity, a two-dimensional forward model has been developed that simulates sedimentation using diffusion processes and is forced by sea-level changes using Milankovitch periods. Finally, several Archean carbonate platforms have been studied and were apparently formed by inorganic precipitation of tremendous masses of aragonite and calcite, suggesting great oversaturation with respect to calcium carbonate in Archean seawater.

In addition to extending their laboratory work on combined-flow stratification in sands by use of larger and more realistic flow channels, Professor John Southard and his students, in collaboration with Professor Grotzinger, have been applying their experimental results to interpretation of Precambrian mixed carbonate-siliciclastic successions that show challenging mosaics of shallow marine to fluvial depositional environments. The first results of an experimental program on downstream fining in aggrading river systems, with colleagues in hydraulic engineering as well as in geology, show that streamwise hydraulic fractionation can account for at least a part of the downstream fining observed in real rivers.

Professor Frederick Frey, working with Dr. Nobu Shimizu from the Woods Hole Oceanographic Institute (WHOI) and graduate student Eiichi Takazawa, has established a geochemical and petrological research program focused on the Horoman Peridotite with the objectives of understanding the formation and migration of melts within upper mantle rocks. Although partial melting within the upper mantle is the major process that creates the Earth's crust, most information about the melting process (e.g., mechanisms of melt segregation, extent of partial melting, and the source compositions) are inferred from the crustal rocks that represent only the partial melts.

Professor Timothy Grove and his students have developed experimental techniques that allow the investigation of basalt magma crystallization under controlled pressure-temperature-volatile content conditions present in the upper continental crust. They have used these methods to determine the factors that lead to the distinctive chemical signatures produced when basaltic magma differentiates to andesite in convergent-margin, subduction-zone settings. An important component in arc magmatism is the presence of water, which is released from the subducted slab, rises into overlying hot mantle, and provides a flux for melting. Professor Grove and students have developed a method that estimates pre-eruptive temperature and water contents in arc lavas.

Professor Roger Burns spent his sabbatical leave at the University of Manchester in England under the sponsorship of a Guggenheim Fellowship award. While at Manchester he wrote the second edition of his book *Mineralogical Applications of Crystal Field Theory*. He also undertook exploratory measurements of surface alteration products forming on sulfide minerals during acid weathering reactions. Using argon ion-beam sputtering to bore through the 25 nanometer surface coatings and Auger electron and x-ray photoelectron spectroscopic techniques to analyze the layers, Burns was able to identify pyrite and x-ray-amorphous nanophase ferric oxide—jarosite—a highly iron-deficient sulfide phase, forming sequentially on oxidized pyrrhotite crystals. The research provides a novel approach for determining the mechanism of oxidation of minerals.

Professor Kip Hodges has moved into a new phase of his research with the establishment of a new rare-gas mass spectrometry laboratory at MIT. This facility, made possible by funds from MIT, Harvard, and the National Science Foundation, was established in April of 1991 and is expected to become fully operational by the Fall of 1991. Professor Hodges, his students, and post-doctoral associates will use this instrument primarily for high-precision geochronology aimed at establishing the cooling histories of metamorphic rocks. Professor Hodges and his students are trying to establish the thermal significance of gravitational collapse in the Nepalese Himalayas and the western United States Cordillera. In the western United States, they have established that gravitational collapse was an important part of the Mesozoic tectonic evolution of the Cordilleran orogen, and they have postulated that the redistribution of material in the evolving orogen was accommodated by flow in a rheologically stratified lower crust.

Professor Clark Burchfiel and Senior Research Scientist Dr. Peter Molnar are conducting studies in the Tien Shan of northwestern China to determine the rate of crustal shortening. The Tien Shan are flanked on the north and south by active belts of folding and faulting that because of excellent exposure in the desert climate afford a unique opportunity to measure shortening rates. Older terraces that cross the folds are deformed more than the younger ones and offer the possibility to measure incremental shortening rates during the past one million to 100,000 years. Measurements of exposure ages to

cosmic radiation, a technique developed by Professor John Edmond and colleagues at MIT, will be attempted to determine the ages of the deformed terrace surfaces. This study forms part of a long-range effort to determine the partitioning of deformation in Asia resulting from the collision and continued convergence of the Indian subcontinent with Eurasia.

Professor Leigh Royden continues her fieldwork in northern Greece where the crustal extension that formed the Aegean Sea also occurs on land. She and her students have mapped several spectacular extensional structures that argue for tens to perhaps more than 100 km of crustal extension in northern Greece in the last 13 million years. This work aims at understanding the relationship between subduction of the Ionian Sea plate to the west of Greece and extension behind this active subduction zone in the Aegean region.

Professor Samuel Bowring and his post-doctoral associate Dr. Todd Housh have set up a new thermal ionization mass spectrometry facility. The centerpiece of the facility is a VG Sector 54 mass spectrometer with seven collectors. The machine is fully operational and routine analyses of U-Pb, Sm-Nd, and Rb-Sr isotopes are underway. The focus of Professor Bowring's research is the origin of continental crust and lithospheric mantle. Professor Bowring and his students are working on a variety of projects that range from the study of remnants of the Earth's oldest rocks in the NW Canadian shield to the Baikal rift zone in Siberia. In particular, Professor Bowring and Dr. Housh are documenting that the oldest rocks on Earth (3.96 Ga) are derived from even older crust and that their chemical and isotopic composition have implications for the earliest history of the Earth and Moon. Another major project underway is the study of how the North American continent grew between 2.0 and 1.0 billion years ago. These studies involve unraveling the history of old mountain belts in the Canadian Shield and the southwestern United States. Recently, Professor Bowring began a project to understand the source regions of basalts in one of the world's largest continental rift zones, the Baikal rift of Siberia. The goals of the research are to document how the composition of basalts in the rift change in space and time, and to use that information to understand better the roles of continental crust, continental lithospheric mantle, and asthenosphere in basaltic genesis.

Geophysics

Professor Thomas Herring has been investigating global dynamical problems using space-based geodetic systems with particular emphasis on the interactions between the rheological properties of the mantle and the dynamics of the fluid core, the oceans, and atmospheres. His research also includes the study of global and regional scale deformation processes using Very Long Baseline Interferometry (VLBI) and the Global Positioning System (GPS), and he is developing improved data analysis techniques for these systems with recent emphasis on atmospheric refraction, satellite orbit modeling, and the applications of Kalman filtering techniques to combined analysis of space geodetic data.

Dr. Robert King, Professor Bradford Hager, Professor Thomas Jordan, and their students are continuing their space geodetic measurements of crustal deformation in central and southern California. Using repeat GPS measurements, they find that the strain building up across the Ventura basin is over twice that associated with the San Andreas fault. They also find substantial strains in the Santa Maria basin and Santa Barbara Channel.

Professor Hager is investigating how space geodesy can be used to monitor global change. He finds that expected changes in ice sheet mass extensive enough to cause observable changes in global sea level also cause elastic displacements of the solid Earth that are large enough to be measured using space geodesy. He is involved in designing a global geodetic network that will have as one of its applications "weighing" changes in ice sheet mass. Hager has also proposed the most detailed model of mantle viscosity structure to date, a model that should allow better determination of global sea level rise through an improved prediction of the relative motion of tide gauges.

Professor Hager and his colleagues are conducting numerical experiments on the MIT Cray-2, investigating thermo-chemical convection in the mantles of the terrestrial planets. Graduate student Steve Shapiro, Professor Hager, and Professor Thomas Jordan have found that the combination of temperature dependent viscosity and compositional buoyancy can explain the stability of the subcontinental lithosphere (tectosphere). Graduate student Peter Puster, Professor Jordan, and Professor Hager are pioneering a new statistical description of the heterogeneities associated with mantle convection. Graduate student Mark Simons, Professor Hager, and Professor Sean Solomon have investigated the interaction of mantle convection and crustal deformation on Venus, constraining their models with the new observations from Magellan.

Dr. Peter Molnar spent a month in Mongolia looking at active faults associated with very large earthquakes. Some of the largest known earthquakes occurred in Mongolia in this century. Together with Mongolian, Soviet, and French colleagues, Dr. Molnar determined amounts of displacements associated with these earthquakes and preliminary rates of recurrence.

Magnetotelluric studies of the California Basin and Range by Professor Theodore Madden and graduate student Randall Mackie have shown this region to have anomalous lower crustal conductivities that must be related to the ongoing extension of the region. In collaboration with graduate student Wenjie Dong, using telluric data from Hollister CA, they

have also been able to identify a conductivity jump at the 670 km discontinuity and the probable existence of small amounts of partial melt in the oceanic upper mantle.

Dr. Robert Reilinger has been using conventional and space geodetic observations to study present day deformation of the Earth's crust (plate motions, earthquake and volcanic processes) in a number of tectonically active areas including the Eastern Mediterranean (with Professor M. Nafi Toksöz), Southern California-Northern Mexico (with Professor Sean Solomon), the Northern Rocky Mountains, and Soviet Central Asia.

Professor Marcia McNutt recently served as Chief Scientist on a month-long expedition of the *Research Vessel Maurice Ewing* to acquire multi-channel seismic reflection data in the Marquesas Islands of French Polynesia. Using 20 air guns and a four km long seismic streamer, she and her colleagues from Lamont-Doherty Geological Observatory recorded 1,400 magnetic tapes of seismic data, increasing by three orders the amount of geophysical information available for this extremely remote area of the Pacific Ocean. Analysis of this large data set will provide new constraints on the deep structure of island chains and the underlying causes of Pacific volcanism.

Professor Daniel Rothman has obtained new results on patterns in multi-phase fluid flow, in addition to developing new models, based on a discrete hydrodynamics, of complex fluid mixtures. One of these new models shows much promise for increasing basic understanding of phenomena ranging from sedimentation to fluidization. In addition, he and graduate student Andrew Gunstensen have developed a new model, based on a Boltzmann equation, for the simulation of three-dimensional immiscible two-phase and three-phase flow. The model is currently being used for the numerical determination of the constitutive equations for multiphase flow in porous media.

Professor Brian Evans and colleagues are investigating the ways in which the strength of faults can recover during the interseismic period between earthquakes. They have shown that faulted rocks may increase in strength by 30 percent or more if hot water is present during quiescent periods. In addition to being strengthened, the rocks tend to fail with larger instabilities than before the healing period.

Professor Sean Solomon spent 1990-91 on sabbatical leave at the California Institute of Technology and the Jet Propulsion Laboratory, where he worked full-time on the analysis of radar images and altimetry of the surface of Venus returned by the NASA Magellan mission. He and his students are focusing on the tectonics of Venus, particularly on the nature of mountain belts, rift systems, and other major deformational features and on the implications of the scales and patterns of deformation for the dynamic and mechanical structure of the planet's interior.

Professor M. Nafi Toksöz, along with graduate student M. Burç Oral, has been working on tectonic deformations in Turkey, Iran, and the Caucasus caused by the convergence of the Arabian Plate against Eurasia. Major earthquakes with magnitudes of 7.0 or greater have occurred in 1983 in Turkey, 1988 in Armenia, 1990 in northwest Iran, and 1991 in the Republic of Georgia on faults activated by the motions of crustal blocks squeezed between the Arabian and Eurasian lithospheric plates. They have been combining finite element modeling with geophysical, geological, and GPS data to determine tectonic deformations and the potential for major earthquakes in continental collision zones.

Dr. Arthur Cheng and graduate student Lisa Block, in cooperation with colleagues from the Los Alamos National Laboratory, developed a tomographic inversion algorithm to image the compressional and shear wave velocity structure and the location of a hydraulic fracture using seismic travel time data collected in the Hot Dry Rock Geothermal project conducted by Los Alamos. This allows the more precise placement of a second borehole to intersect the fracture, providing a path to extract geothermal energy by circulating water through it.

Professor Thomas Jordan and Dr. William Rodi have been developing mathematical tools for deducing the properties of objects such as the Earth from complex data sets, such as those provided by seismology, based on the concept of "hierarchical inversion"; the procedures they have investigated appear to have several advantages over currently used formulations, especially for ill-posed, nonlinear inverse problems. Using novel techniques for the analysis of low-frequency seismic waves recorded at teleseismic distances, Professor Jordan and his students have also discovered that some large earthquakes appear to have short-term, slow precursors. This work may help to elucidate which earthquakes are short-term predictable by near-field monitoring.

Planetary Science

Professor Gordon H. Pettengill continues his involvement in the Magellan radar mapping mission to Venus, which has returned extremely high-resolution synthetic-aperture images of more than 80 percent of the planet's surface since reaching Venus in August 1990. Using data from an ancillary radar altimeter on board the orbiter, he has supervised the preparation of global maps of the topography and surface electrical properties using facilities at the MIT Center for Space Research. Together with Professor Sean C. Solomon, Professor Pettengill is also involved in an experiment using a laser altimeter to be placed in orbit around Mars in 1993, with the aim of yielding a high-resolution map of the topography of that planet.

Professor Richard P. Binzel has been pursuing observational and theoretical analysis of an asteroid in advance of the first flyby of the Galileo spacecraft in October 1991. Observations and analyses for estimating the size, shape, and spin-vector for the target, 951 Gaspra, have been forwarded on to the Galileo team for encounter sequence planning. Theoretical modeling of Gaspra's collisional environment has also been performed to predict (and interpret) the surface cratering distribution.

Professor James Elliot and graduate student Leslie Young have devised a new technique for extracting thermal gradients from stellar occultation data on planetary atmospheres. Applying this method to their 1988 Pluto data, they have established the thermal structure of Pluto's atmosphere more reliably than has been possible previously. Their results support the "methane-thermostat" mechanism as determining the atmospheric structure of Pluto. Testing of the High-Speed Photometer aboard the Hubble Space Telescope is nearly complete, and the investigations of the atmospheres and rings of the outer planets planned by Professor Elliot's group will begin next fall.

Professor Timothy Dowling is modeling the global circulation of the giant planet atmospheres. A breakthrough came recently when, for the first time, he and his colleagues initialized a numerical model of Jupiter's atmosphere with the Voyager wind-field data and found that Jupiter's Great Red Spot arises spontaneously from an instability inherent in the jet stream profile. Interestingly, the ease with which the model reproduced the Red Spot may provide a clue to the formation of the giant planets themselves out of the proto-planetary disk, an angle that they are actively pursuing. They have nearly completed construction of a Flow Visualization Laboratory that is designed to allow them to make interactive videotape results of their numerical experiments on a daily, rather than yearly, basis.

Dr. Heidi B. Hammel is continuing her analysis of simultaneous ground-based and spacecraft imaging of Neptune obtained during the 1989 Voyager Encounter with Neptune. She took the ground-based images with the University of Hawaii 2.2-meter telescope at Mauna Kea Observatory during Voyager's closest approach to the planet. The ground-based data extend the wavelength coverage out to near-infrared wavelengths and directly link the Voyager imaging with past and future Earth-based observations. Dr. Hammel is also making exploratory observations of the thermal infrared spectra of Pluto and Triton using NASA's Infrared Telescope Facility in Hawaii.

Professor Jack Wisdom continued his studies of the long term evolution of the solar system. He has recently developed a new integration algorithm that is an order of magnitude faster than conventional integration methods. With this new method he has carried out several new billion year integrations of the outer planets and verified his earlier result, with Professor Gerald Sussman, that the motion of the planet Pluto is chaotic.

Professor Charles Counselman and colleagues are developing a system to monitor strain accumulation in the crust of the Earth regionally and globally. Radio signals from tiny transmitters distributed throughout areas being monitored are relayed by satellites to central processors that determine the positions of the transmitters from the phases of the signals. Tens of thousands of points, distributed throughout Japan and the state of California to form an earthquake warning system, may be monitored continuously and simultaneously. Proof-of-concept experiments using phase measurements of similar signals transmitted by satellites and received at the monitored Earth-surface points have yielded daily strain-measurement precision of one part in 50 million.

THOMAS H. JORDAN

Department of Mathematics

DEPARTMENTAL STATISTICS

Students

During the academic year 1990-91, there were 203 undergraduates majoring in mathematics, 152 in Course XVIII, Mathematics, and 51 in Course XVIII-C, Mathematics/Computer Science. Bachelor of Science degrees were awarded to 64 students, 46 in Course XVIII including the double majors, and 18 in Course XVIII-C.

There were a total of 118 graduate students in mathematics, all in the Ph.D. program. This year 27 students received their Ph.D., including 18 this last June.

Faculty

There were 53 faculty members in the Mathematics Department, 21 in the Applied Mathematics group, and 32 in the Pure Mathematics group. This included the following on whole or partial leave:

- Assistant Professor David Anick (fall term)
- Professor Alexander Beilinson (spring term)
- Professor Kenneth Hoffman (year) as Executive Director of Mathematical Sciences Educ. Board of the Natl. Academy of Sciences - Natl. Research Council
- Professor Victor Kac (spring term)
- Professor Bertram Kostant (spring term)
- Professor Richard Stanley (fall term)
- Associate Professor L. Nick Trefethen (year)

There were three Visiting Professors this year; Professor Isom Herron from Howard University, Professor Ivanovich Manin (fall term) from Steklov Mathematical Institute, USSR, and Professor Helmut Rieder from University of Bayreuth, Germany. There were two Visiting Associate Professors; Zoltan Furedi (spring term) from The Mathematical Institute, Hungarian Academy of Sciences, and Leon Van Dommelen from Florida State University. There was one Visiting Assistant Professor, Walter Olbricht from Ruhr-University, Bochum, Germany.

FACULTY CHANGES

Retirements and Resignations

Assistant Professor Mark Haiman resigned from MIT this year, accepting a position at the University of California, San Diego.

Assistant Professor Ali Nadim resigned to accept a position at Boston University, Department of Aerospace & Mechanical Engineering.

Associate Professor Lloyd Nick Trefethen resigned to assume a position at Cornell University, Department of Computer Science.

New Appointments

Dr. Mark Matthews has accepted a position as Assistant Professor of Applied Mathematics; his specialty is Probability and Statistics.

To date, five distinguished faculty will join us as Visiting Faculty next year; Professor William Dwyer from University of Notre Dame, Associate Professor James Fill from Johns Hopkins University, Dr. Narendra Karmarkar from AT&T Bell Labs, Professor Menachim Magidor from Hebrew University, Israel, and Professor Daniel Quillen from Oxford University.

Promotions

Associate Professor Michael Hopkins was promoted to full Professor. His field is Algebraic Topology.

Honors, Prizes and Awards

Assistant Professor Ezra Getzler was selected as an Alfred P. Sloan Research Fellow to support his research over a 2-year period.

Professor Sigurdur Helgason received the Major Knight Cross of the Icelandic Falcon from the President of Iceland, Vigdís Finnbogadóttir, in recognition of his mathematical research.

Assistant Professor Steven Strogatz received the Everett Moore Baker Award for Excellence in Undergraduate Teaching.

Phyllis Ruby, the Graduate Student Administrator, received the James N. Murphy Award for sustained, dedicated service to students.

Three graduate students, Eric Babson, Richard Kerswell and Esteban Tabak, received Alfred P. Sloan Doctoral Dissertation Fellowships.

Senior Charles Waldman was awarded the Jon A. Bucsela Prize in Mathematics in recognition of distinguished scholastic achievement, professional promise, and enthusiasm for mathematics.

Six seniors in mathematics were elected to the national honor society Phi Beta Kappa.

ADMINISTRATION

Professor Victor Guillemin is Chairman of the Pure Mathematics Committee while Professor Bob MacPherson takes a year's leave of absence.

Professor Alar Toomre succeeds Professor Daniel Kleitman as Chairman of the Applied Mathematics Committee.

Professor Sy Friedman succeeds Professor David Jerison as Chair of the Undergraduate Committee. The following committee chairs remain the same:

Professor Sigurdur Helgason - Graduate Committee
Professor James Munkres - Committee of Advisors.

EDUCATIONAL

Among the educational initiatives of the department, here are the ones that involve the undergraduate core.

This year an unsuccessful attempt was made to try out the computer software *Mathematica* on a cluster of Macintosh computers not yet integrated into the Athena network. An undergraduate and a graduate student were hired over the summer to attempt to make *Mathematica* easy to use even by novices. The extra code produced turned out to be unstable. More importantly, the teachers of the first and second calculus courses could not figure out how to make adequate use of *Mathematica* to justify the extra time required of students. The only consistently stable and useful software that we currently have is Athena-based software for ordinary differential equations. Edward Moriarty, Project Manager in the Electrical Engineering Department, is developing a new, more flexible system that may allow us to add applications for the calculus courses.

Efforts to help the least prepared students have continued. This year, a diagnostic exam was administered to a random sample of about 150 students in the first calculus course, 18.01 Calculus. At the instigation of Professor Anthony French in the Physics Department, a diagnostic test in high school mathematics will be administered to all 1000 incoming students.

The mathematics department has assisted Professor French in preparing the exam and in arranging for assistance to those students who perform poorly. A warm-up test was sent to all incoming students at the beginning of the summer, and pamphlets (in preparation) with exercises covering each topic on the exam will be sent to students who want them over the summer. In the fall term, workshops and tutoring to review high school mathematics will be offered through at least the first week of classes. This program will be organized by Lecturer Peter Dourmashkin, who coordinates various tutorial programs, Excel (XL) and Experimental Studies Group (ESG), and teaches physics for the summer InterPhase program. The mathematics department will provide exercises for the review sessions, and many of the tutors will be mathematics undergraduates and graduate students.

DAVID J. BENNEY

Department of Physics

During the past year, all major research programs in the Department have remained active and some important new initiatives have been started, as described in the detailed accounts later in this report. The Department has continued to address the challenge it faces as a major component of the MIT educational program.

The members of the Physics Department continue to provide leadership for the major MIT interdepartmental laboratories. At present the directors of the Laboratory for Nuclear Science (LNS), Bates Linear Accelerator (BLA), National Magnet Laboratory (NML) and Spectroscopy Laboratory are members of the Physics Department, as well as the Associate Directors of both the Research Laboratory of Electronics (RLE) and the Plasma Fusion Center (PFC), with Professor J. David Litster appointed acting Vice-President for Research. In 1990-91 the total number of faculty was 86. The following faculty members received promotions: to Associate Professor without Tenure, Edmund Bertschinger and Leonard Gregor Hertel. Two new Assistant Professors joined our faculty: Roger Brooks and Boleslaw Wyslouch. Five members of the faculty retired: Anthony P. French, K. Uno Ingard, Felix Villars, Peter Wolff, and James Young.

Faculty on leaves or sabbaticals during the year included: Professors John Belcher, Bruno Coppi, Daniel Kleppner, Aneesh Manohar, Louis Osborne, Peter Wolff and James Young.

A number of faculty received awards during the past year. Professor Edmund Bertschinger was named to the Class of 1956 Career Development Professor of Physics. Professor Jacqueline Hewitt received the David and Lucile Packard Foundation Fellowship, as well as being designated by the National Science Foundation as a Presidential Young Investigator (PYI). Professor Hale V. D. Bradt received the 1990 Buechner Prize in recognition of outstanding contributions to the educational program of the Department. Professor Mehran Kardar was named the Class of 1948 Professor and received the Edgerton Award for outstanding achievement in research, scholarship and teaching.

Professor Patrick A. Lee received the 1991 Buckley Prize in Condensed Matter Physics from the American Physical Society. He was also elected to the American Academy of Arts and Sciences. Professors Jerome I. Friedman and Henry W. Kendall were awarded the 1990 Nobel Prize in Physics for their experiments that confirmed the existence of quarks. Professor Friedman was also named Institute Professor in May 1991. Professor Mildred Dresselhaus received the National Medal of Science for her studies of electronic properties of metals and semimetals and for her service to the nation in establishing a prominent place for women in physics and engineering. Professor Daniel Kleppner was awarded the 1991 Julius Edgar Lilienfeld Prize from the American Physical Society for outstanding contributions to physics by an individual with exceptional skills in presenting lectures to general audiences. He was also presented with the 1991 William F. Meggars Award by the Optical Society of America. Professor David E. Pritchard was awarded the 1991 Herbert P. Broida Prize, recognizing his outstanding experimental advancements in the field of atomic physics. Professor Saul Rappaport was elected as a new American Physical Society Fellow. Professor Robert J. Birgeneau, Head of the Department of Physics, was appointed Dean of the School of Science effective July 1, 1991.

With regard to student honors, the 1990 Buechner Student Teaching Prize was awarded to Roberta Brawer. Joel R. Phillips was awarded the David Adler Memorial Thesis Competition Prize as well as the Joel Matthew Orloff Undergraduate Research Opportunities Program, or UROP, Award. Lori M. Lubin received the Association of MIT Alumnae Award. Jonathan I. Rockman received the Edward S. Darna Award and the DeWitt Wallace Prize. Sanjeev Agrawal received the 1991 Henry Ford II Scholar Award. Michael A. McDermott received the Joel Matthew Orloff UROP Award. Michael Rizen was awarded the Randolph G. Wei Undergraduate Research Prize and won the Ernst A. Guillemin Thesis Competition. Fourteen students were elected to Phi Beta Kappa: Sanjeev Agrawal, Vijay Balasubramanian, Bennett H. Brown, Yildiz R. Dalkir, Tomislav Kundic, Lori M. Lubin, Matthew D. McCluskey, James Nagle, Saewoo Nam, Joel R. Phillips, Michael Rizen, Emmmin Shung, Aaron Sodickson and Esteban R. Torres. Esteban R. Torres was also presented with the Henry Webb Salisbury, '33 Award. James Bales and Andrew Greene both received the William L. Stewart Jr., '23 Award, and Army Cadet Peter O. Rexer received the Hovnanian Memorial Scholarship. Steven D. Penn received the Karl Taylor Compton Prize.

EDUCATIONAL ACHIEVEMENTS

The Department has continued to maintain a consistent number of graduate and undergraduate students as well as a relatively constant number of credit units per faculty member. This year the number of undergraduate majors was 218 and the number of graduate students was 302. The number of degrees awarded totaled 64 S.B., 2 S.M., 19 Ph.D.

CURRENT RESEARCH

Astrophysics Division

Research in the Astrophysics Division deals with phenomena ranging from the earth's magnetosphere to the most distant quasars. Observational programs involve the collection, analysis and interpretation of data from a wide variety of ground-based and space based observatories. There are major efforts for the development of new instrumentation to detect cosmic radiation across the electromagnetic spectrum, from radio to gamma rays. Theoretical research is carried out on topics ranging from plasma physics in the solar system, through stellar evolution, to the large scale structure of the universe.

1. High Energy Astrophysics

Observational programs in X-ray astronomy rely on the extensive data archives from previous space missions and on collaborative programs involving Japanese and European satellites. Last year's launch of the German ROSAT telescope will provide MIT researchers with new observational opportunities. Related observations are also made using ground based optical and radio observatories, including the Michigan-Dartmouth-MIT (MDM) observatory. A study of the global multiwavelength properties of active galactic nuclei (AGN) and cataclysmic variables uses data from many satellites including IRAS, Ginga, and ROSAT. Individual objects include an irregularly varying cataclysmic variable with an asynchronous spin-orbit rotation which places it in a unique evolutionary state. There are several programs involving optical observations designed to identify sources found in the ROSAT survey, which will yield nearly 100,000 new X-ray sources. Most of these observations are being performed at the Michigan-Dartmouth-MIT (MDM) observatory. One program is focusing on finding sources in the Galactic plane, while another concentrates on our neighbor galaxy M31 (Andromeda). The group has just completed a catalog of X-ray spectra from the Einstein Observatory (HEAO-2) spectrometer. Specific studies of the spectra of supernova remnants and active galaxies are also being pursued, including a supernova remnant in the Large Magellanic Cloud found to be extremely rich in oxygen. A study of low-mass X-ray binaries with data from Ginga and EXOSAT has elucidated the relation between the radio emission of bright low-mass X-ray binaries and their X-ray emission. Another program is investigating the atmospheric and wind structures of the companion stars of X-ray pulsars using data from the Ginga satellite. Upcoming ROSAT observations will study the shapes of the gravitational potentials of elliptical galaxies to address the question of the distribution of dark matter in their halos. Another observational program with ROSAT will search for X-ray emission from the objects responsible for gamma ray bursts. Optical flashes from gamma ray bursts (detected with the recently launched Gamma Ray Observatory) are being searched for with the Explosive Transient Camera located on Kitt Peak.

Several major instrumentation projects are underway including design and definition of instruments for the Japanese Astro-D mission, which will be launched in February 1993, the X-ray Timing Explorer, the Advanced X-ray Astrophysics Facility, the Explosive Transient Camera, and the High Energy Transient Experiment. Details are given in the report of the Center for Space Research.

2. Radio Astronomy

A major activity in the radio astronomy group is the study of gravitational lenses. Since 1979, the flux densities of the components of the gravitational lens 0957+561 have been monitored with the Very Large Array. Combining the radio data with similar observations in the optical shows that the signals vary but with a time delay of 1.48 years. The measurement of the time delay in 0957+561 can

be used to place bounds on the value of Hubble's constant. Uncertainty in the gravitational lens model for the system yields a range of 28 to 83 km/sec-Mpc, which is a fully independent measure of this fundamental cosmological parameter. New candidate lens systems, identified in a large radio survey, are being studied to determine whether they are indeed lensed. VLA observations of the first Einstein Ring gravitational lens, MG1131+0456, are being carried out this year to investigate whether there is sufficient variability in the source to justify a monitoring program aimed at a determination of Hubble's constant. An Einstein Ring lens is particularly well suited to this application, since the symmetry of the imaging removes many of the model uncertainties associated with other less symmetric systems.

A separate program involves Very Long Baseline Interferometry (VLBI) observations of dMe stars, dwarf M stars that show evidence for surface activity. The detection of dMe stars on VLBI baselines makes possible the measurement of the position of these stars with high precision, and the astrometric detection of planetary companions may be feasible. Initial observations have investigated the nature of the radio emission, and have identified extragalactic radio sources suitable as positional references for the stars AD Leo, EV Lac, and YZ CMi. First-epoch VLBI astrometric measurements were carried out last June using a VLBI array composed of telescopes in the United States, Spain and Germany. The correlation of the data is complete, and the current effort is the calculation of phase-referenced maps of the dMe stars. Other future techniques for the detection of planetary systems are being explored as part of a broadly based NASA sponsored study. The radio astronomy group is also participating in the Soviet and Japanese space VLBI missions which are scheduled to take place in 1994/95.

3. Optical Astronomy

The main MIT facility for optical astronomy is the Michigan-Dartmouth-MIT observatory in Arizona, which has a 1.3m and a 2.4m telescope with modern instrumentation. Researchers also make regular use of the telescopes of the National Optical Astronomy Observatory in Arizona and Chile, telescopes in Hawaii, Las Campanas and Mount Palomar. Observational programs are carried out by many of the groups in the Astrophysics Division. There are active programs for the identification and study of X-ray sources and of gravitation lens candidates from radio surveys, which are described above.

One observational program involves measurement of surface brightness fluctuations which arise from the counting statistics of stars in external galaxies. This can give exceedingly accurate distances to these galaxies, which in turn gives the Hubble constant and information about the stellar population of the galaxy. Many observations were required to calibrate this method, which was then applied to the local group galaxies M31, M32, and NGC 205. The distance to these galaxies is known from other methods, and they therefore serve as absolute calibrators. Additional observations of galaxies in nearby clusters, Fornax and Eridanus, leads to a value of 82 km/s-Mpc for the Hubble constant.

Work has continued on mapping the structure of our Galaxy by precise observations of individual stars in the galactic disk. Published radio observations of neutral hydrogen emission in the plane of the Milky Way have been used to correct for interstellar absorption and determine the intrinsic infrared colors of carbon stars. Cepheid variable stars are being studied with the goal of determining a better distance to the Galactic center. Observations of a sample of 38 candidate variable stars confirm that nine of these are new Cepheids (among the most distant known) and yield periods for them. Observers have measured radial velocities accurate to 0.8 km/s at a number of different epochs for a sample of 40 distant Southern hemisphere Cepheids and has determined center of mass velocities for these and a previously studied Northern hemisphere sample.

4. Observational Cosmology and Gravitation

Data from the Cosmic Background Explorer (COBE) Mission have provided important new results on the spectrum and isotropy of the microwave background. Results from the analysis of the data taken during the cryogenic phase of the mission include: an upper limit for the Comptonization parameter $y < 0.0001$, upper limits on the quadrupole anisotropy of 0.00003 upper limits of 0.0001 on anisotropy on all angular scales larger than 7 degrees, the first detection of the interstellar NII line at 205.3

micron, maps of the CII, NII and dust distribution in the galaxy, and upper limits for a cosmic infrared background. COBE continues to take data on the anisotropy of the CBR on angular scales 7 degrees and larger at 30, 50 and 90 GHz and maps the sky in four bands between 1 and 5 microns.

The MIT balloon-borne radiometer operating as a survey instrument with a 3.5 degree beam has mapped about 1/3 of the sky in four spectral bands near 1 mm wavelength. The measurements measure the anisotropy in the cosmic microwave background radiation as well as mapping the Galaxy in the sub-millimeter band. The data have been used to test for limits on anisotropy for both Gaussian shaped correlation functions and power law correlation functions. These data place the most stringent limits on models for large-scale structure growth of any to date and any angular scale.

The Laser-Interferometer Gravitational Wave Observatory (LIGO), a joint project of Caltech and MIT to develop and construct two 4km baseline gravitational wave interferometers to detect gravitational waves originating from astrophysical sources. Current research has been dedicated to improving the performance of a 40 meter prototype at Caltech, demonstration of interferometric techniques applicable to the large scale system, and improvements in ground noise isolation and reduction in the influence of thermal noise.

5. Space Plasma Physics

The Space Plasma Group has finished the summary reports on the magnetosphere of Neptune. Extensive analysis of the plasma data gathered in the magnetosphere of Neptune over the last two years since the 1989 encounter has revealed that the two ion species, H⁺ and N⁺, escape from Neptune's large satellite Triton and the from a neutral torus originating from Triton. Precipitation of plasma into Neptune's atmosphere and ring absorption are important plasma loss mechanisms. In addition to studies internal to the Neptune magnetosphere, the Voyager 2 flyby of Neptune occurred when the (tilted) magnetic dipole of the planet was pointed into the solar wind flow. This allowed the study of a supersonic flow/magnetic dipole interaction in a configuration never before observed. The measured plasma parameters near the interface between the solar wind and the region dominated by the planetary magnetic field demonstrate the existence of a mantle-like layer of dynamic plasma where solar wind plasma has direct access to the magnetosphere along open magnetic field lines. These studies have made major contributions to the understanding of the access of external plasma to magnetospheric interiors.

6. Theoretical Astrophysics

Studies have been made of the large scale structure of the universe and departures from the smooth Hubble velocity flow in the context of a universe dominated by cold dark matter. A method has been devised for reconstructing the three-dimensional velocity and density fields of cosmic dark matter on large scales, starting from galaxy distance and radial velocity measurements. This technique has been used to map the cosmological matter distribution and to estimate the total mean mass density in the universe. Large computer simulations of the formation of galaxies and large-scale structure by gravitational instability are being used to test theories of cosmological structure formation. These simulations, presently the largest in the world, have shown that some of the key conclusions of earlier simulations were flawed by inadequate resolution, and they suggest that the theory of galaxy formation with cold dark matter and primordial cosmic inflation may still be viable, contrary to several recent reports.

Further developments in the theory of the inflationary universe have permitted consideration of the possibility of creating a new inflationary episode in the present universe (i.e. creating a universe in the laboratory) as a result of quantum tunneling beginning with a classically produced bubble of false vacuum that itself is not sufficiently large to evolve into a new universe. A separate investigation is exploring the quantification and comparison of the amount of fine-tuning of parameters that is needed in a variety of inflationary models in order to set bounds on broad classes of models.

Work has continued on relativistic plasmas and their applications to quasars and active galactic nuclei. It has been found that accretion disks are subject to electron-positron pair-driven instabilities and have no equilibria at all for luminosities in excess of 1 per cent of their Eddington limit. The subsequent collapse of the disk and change in its luminosity and spectrum are observable

consequences and may provide important diagnostics for the central engine of quasars and active nuclei.

In the area of star formation and early stellar evolution, a kinematical model for the structure and evolution of protostellar disks has been constructed, leading to a study of its radiation and to observable predictions for detection of such disks in the infrared. The first detailed study of the luminosity function of young, embedded stellar clusters has been completed and has been compared to observational results. A numerical study of protostellar evolution of intermediate mass stars has led to the discovery of an extension of the stellar birth line into this mass region, a result that shows excellent agreement with the distributions of young Ae and Be stars in the luminosity-temperature diagram.

A continuing study is being carried out of the evolution of close binary star systems containing a collapsed star (neutron star, degenerate dwarf or black hole) in which mass transfer is driven by expansion of the companion star as it evolves or by shrinking of the binary system due to gravitational radiation and magnetic braking, or by the effects of X-ray heating of the companion. Systems modeled include cataclysmic variables and related ultracompact binaries with orbital periods as short as 11 minutes, low-mass X-ray binaries, gamma ray burst sources, globular cluster X-ray sources, recycled binary and isolated millisecond radio pulsars and supernova 1987a. MIT faculty co-organized a six month long workshop on Neutron Stars in Binary Systems at the Institute for Theoretical Physics at Santa Barbara.

Atomic, Condensed Matter, and Plasma Physics Division

Condensed Matter

1. Scaling Behavior in High Temperature Superconductors

The experimentalists in the physics department studying high-temperature superconductivity have been working, since the discovery of this new phenomenon, to understand in what way the magnetic and transport properties of the normal state of the metal are related to the superconductivity. Recent neutron scattering experiments have revealed highly unusual behavior in the magnetic scattering of the high-temperature superconductor $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$, which may provide a clue to this relationship.

The MIT group discovered two years ago that antiferromagnetic correlations of the spins on the Cu atoms were present even in the superconducting materials. The new results have revealed that the inelastic scattering strength of the magnetic fluctuations scales with ω/T where ω is the energy transfer from the neutron to the spin system and T is the absolute temperature. This behavior is different from that in all previously studied magnetic systems. Furthermore, this scaling behavior is sufficient to explain a variety of other unique properties of the high T_c materials including, for example, the resistance, which is found to be linear in T . Recent magnetoresistance experiments suggest that inelastic magnetic scattering may, indeed, dominate the charge transport. The neutron scattering experiments may thus provide a unified picture of the various peculiar normal state properties of high T_c superconductors, an important step on the way to developing a theory for the new superconductivity.

2. Quantum Transport for Strongly Localized Electrons

There is much current interest in the influence of quantum mechanics on electronic systems whose physical size is very small. The positive magnetoconductance and the reproducible fluctuations observed in the conductivity of small wires are manifestations of such quantum mechanical behavior. Most studies have focused on metallic wires, or systems close to the metal-insulator transition, where the perturbative (weak localization) theories can be applied. By contrast, there is much less understanding of characteristic fluctuations on the insulating side, where electronic states are strongly localized and the main mechanism for conductivity is by variable range quantum tunneling. In the current work numerical simulations and analytical arguments have been applied to the study of quantum interference effects for strongly localized electrons.

As a first step the probability distribution for tunneling was studied as a function of the separation between localized sites. This distribution is very wide (log-normal), but governed by a universal probability distribution. Additional work revealed how this distribution is modified in the presence of a magnetic field, and by impurities causing spin-orbit scattering. In the absence of such scattering, a magnetic field leads to an increased localization length, hence a large positive magnetoconductance. With scattering, there is no change in the localization length, although there is a small positive magnetoconductance due to the change in an overall amplitude. These results are in qualitative agreement with preliminary experiments, but in sharp contrast to most previous theories.

3. Phase Transitions in Semiconductor Surfaces

Elemental semiconductors, in particular silicon, are at the foundation of the electronics industry. The structures and morphologies of semiconductor surfaces are manifestly of fundamental importance. One central issue is the nature of such surfaces at high temperatures where growth and materials processing typically are carried out. In spite of the evident importance of the high temperature properties of semiconductor surfaces, rather little is known about them. This is because standard surface probes such as low energy electron diffraction and scanning tunneling microscopy are very difficult, if not impossible, to implement at high temperatures. However, these difficulties can be circumvented by using high resolution synchrotron x-ray scattering techniques.

High resolution x-ray diffraction studies have been carried out on two different semiconductor systems: flat Ge(111) and vicinal Si(111), that is, Si(111) miscut at a small angle (3.3° in the 112 direction). Previously, Ge(111) was reported to undergo some sort of disordering transition at ~ 1050 K. The nature of this disordering was, however, controversial. The current work demonstrates conclusively that there is no real phase transition. Rather, the topmost layers disorder progressively with increasing temperature, albeit retaining long-range order up to at least 1150 K. Neither diffuse scattering associated with roughening or surface melting nor effects due to surface incommensurability are observed. The data are best described by a model in which the surface vacancy concentration grows rapidly between 1000 K and 1100 K and then saturates. The vacancy concentration is near 50 percent above 1100 K.

The work on vicinal Si(111) represents the first generation of such experiments. At temperatures above 1120 K the diffraction pattern is consistent with a lattice of steps which are, on average, uniformly spaced. However, the steps wander over large distances yielding a unique "power law singularity" line shape for the diffraction peaks. Below 1100 K the flat (111) surfaces reconstruct into the well-known 7×7 pattern. This causes the flat terraces to grow enormously in size and the steps actually phase separate. The detailed behavior of the surface at this novel phase separation is currently being explored.

4. New Phases of Gels

Synthetic polymer gels have been known to exist in two phases, swollen and collapsed, separated by a well-defined phase transition. The transition is a result of a competitive balance between a repulsive force that acts to expand the polymer network and an attractive force that acts to shrink the network. The repulsive force is introduced by charge-charge interaction. On the other hand, four different attractive interactions are known in biological systems: hydrogen bonding, hydrophobic interactions, van der Waals interactions, and ionic interactions. Physicists at MIT have succeeded in inducing gel phase transitions driven by each one of these interactions separately. This has opened the door to a quantitative understanding of these fundamental interactions.

The next logical step was to study a gel in which two or more interactions are combined. Would the gel have new phases other than just swollen or collapsed states? Such phases are known in the biological world. Every protein has a unique and stable structure. It must be at its free energy

minimum, separated by free energy barriers from other possible configurations. By thermodynamic definition, a protein should be in a phase. Similarly, antibody-antigen pairs and the DNA double-helix should be phases. Until now, however, no such phases had been observed in synthetic polymers.

This situation has changed dramatically due to recent work at MIT. Advances in gel research were made which led to the discovery of new phases in copolymer gels consisting of cationic (+) and anionic (-) groups that form internal hydrogen bondings. As temperature or pH is varied the gel changes its volume discontinuously in water among many phases distinguished by different volumes. The number of phases and the transition thresholds depend on the ratio of the cationic and anionic monomers in the polymer network. Each phase can be reached by following a different way of changing pH. New phases have also been discovered in other gels.

These results demonstrate that the marvelous functions and structures, once considered to be available only to biopolymers, may be achieved by ordinary synthetic polymers. Conversely, the findings will introduce into polymer science the concepts and principles of specificity, individuality, and diversity: Macroscopic behaviors of polymers are far richer than one used to think and crucially depend on how the fundamental interactions are coordinated within the polymers.

Atomic

1. An Atom Interferometer

A major advance was made in the field of atom optics: the demonstration of the first atom interferometer--a three-grating interferometer for sodium atoms. (Multi-slit and two-slit interference has been seen with atoms before.) This configuration is much like a Mach-Zender interferometer: The first transmission grating splits the incident atom wave into coherent beams, two of which are diffracted by the second grating so they recombine at the third. The interferometer, including collimator, is about two meters long, and the two components of the atom wave are separated by 27 m in the middle of the interferometer.

The key component of the atom interferometer is the transmission grating for atoms. The gratings in the interferometer consist of a set of slots in a silicon nitride membrane stretched across openings in a silicon wafer. The gratings used in the interferometer had a 0.4 m period. There are also plans to use similar nanofabrication techniques to make other elements of atom optics such as zone plates.

Atom interferometers should be valuable for three general classes of measurements: inertial effects, fundamental tests, and measurements of atomic and molecular properties. Atom interferometers are particularly sensitive to rotation, having $\sim 10^{10}$ the sensitivity to rotation of a laser gyro with the same beam geometry. These improvements in atom optics may ultimately permit the construction of gyroscopes good enough to perform tests of relativity. Atom interferometers are ideally suited to measurements of quantum topological phases, such as the recently predicted Aharonov-Casher phase resulting from the transport of a magnetic dipole around a line charge. Electric polarizability is an atomic property that is ideally measured in an interferometer by imposing a uniform electric field on the atom waves on one side of the interferometer.

Plasma

1. Suppression of Instabilities in Fusion Plasmas

Plasma theorists in the Division have been studying a peculiar phenomenon in plasmas known as "magnetic reconnection." The phenomenon is most familiar to those working with astrophysical plasmas, since it plays a role in the characteristics of the earth's magnetosphere and the dynamics of solar flares. Recent developments have brought the topic of magnetic reconnection down to earth.

The continuing efforts to push fusion plasmas to higher temperatures and densities encountered a serious problem due to a particular instability in the plasma. The instability manifested itself as a sudden "crash" of the temperature in the central part of the confined plasma column. The MIT group proposed that the instability was associated with the development of magnetic reconnections. They not only developed a full theory of the instabilities, but also predicted that the instabilities could be suppressed by the development of a population of high energy helium particles in the center of the column. An important test of the theory was provided when the team that operates the Joint European Torus (JET) in England--the largest device of its kind--succeeded in using this method to suppress the instability. Successive experiments on other machines have confirmed the JET findings and validated other aspects of the theory as well.

Experimental Nuclear and Particle Physics Division

1. Medium Energy Nuclear Physics

a. Few-body Systems

The electromagnetic structure of the nucleon and of the simplest nuclei, those amenable to microscopic theoretical analysis based upon the best available models of the nuclear force, continue to be a major focus of the Bates research program. A double-scattering experiment examining the polarization observables in electron scattering from deuterium has provided the first full characterization of the ground state charge structure of this most elementary nucleus. The experiment has reinforced the appropriateness of hadronic descriptions at length scales well below 10-13cm. Another measurement has provided the magnetic structure of deuterium to very small distance scales, showing the importance of mesons. Nucleon structure is being explored in several ways. The neutron charge distribution will be measured in two complementary ways. One involves scattering polarized electrons from polarized ^3He nuclei. The second involves a double scattering experiment measuring the polarization of neutrons knocked out from deuterium. Another program will examine the deformation of protons. All of these programs require major technical developments and involve a novel use of polarization observables. The polarized target development provides the basis for our leading role in a major experiment planned at DESY (Hamburg) which will measure proton and neutron quark distributions.

b. Electron, Proton Coincidence Experiments

Electron-proton coincidence experiments continue to be an important program at Bates. An extensive program using carbon as a target has yielded a series of important results. A measurement made to very large momentum transfer, 1 GeV/c, is consistent with the proton maintaining its integrity in the nuclear medium. Furthermore, a surprisingly large yield of deuterons has been found, suggesting further studies of the correlation structure of nuclei. A new set of precision measurements on the deuteron has begun, using the first of a set of four out-of-plane spectrometer under construction.

c. Parity

Parity non-conservation, a violation of reflection symmetry in nature, arises from the weak force. The very small difference (less than one part per million) in scattering electrons in two different polarization states from a spherical nucleus was measured at Bates. The difference was found to be consistent with that expected in the Standard Model of elementary interactions. The next such experiment will measure parity violation in electron-proton scattering and is now in the testing phase. The result will provide the first experimental information on the strange quark contribution to nucleon magnetism.

d. Pion Physics

Most of the current work outside the Bates Laboratory involves pion induced reactions at Los Alamos and PSI. An extensive program of charge exchange measurements is continuing at LAMPF. The MIT group helped build a new large acceptance detector for studying pion absorption at PSI. The first data obtained with this detector are in the final stage of analysis.

e. South Hall Ring

The Bates research program has done much to frame the questions and to establish the experimental basis for the future electronuclear studies needed to advance nuclear physics along new directions. The new capabilities needed have been identified: continuous (CW) beams and full utilization of polarization observables. The South Hall Ring (SHR) project at the Bates Laboratory is an experimental initiative which will provide these capabilities throughout the important energy range accessible to the existing accelerator (i.e., up to 1 GeV). The South Hall Ring will be completed in 1992. It will be an integral part of the South Experimental Hall using existing beam lines for experiments in the internal target mode and in the extracted beam mode.

In the internal target mode, the electrons are circulated thousands of times through a windowless gas target introduced into the ring. The major benefit of this configuration is that it permits (and requires) the use of exceedingly thin targets, i.e., targets so thin that an insufficient number of interesting collisions would take place if each electron passed through the target only once. There are several advantages to this approach. One is that heavily ionizing reaction products are able to leave the target and reach the detector. This possibility is central to a number of planned experiments, for example, those aimed at a basic understanding of nuclear fission or of the propagation of pions in the nuclear interior. Perhaps the most exciting prospect, however, is that associated with polarization. Advances in laser technology and surface science now make it feasible to produce gases of polarized nuclei of sufficient thickness for internal target use. Such internal target experiments, representing a significant departure from the traditional experimental configuration in electronuclear physics, will require innovative developments advancing both physics and technology. A major new detector called BLAST (Bates Large Acceptance Spectrometer Toroid) is being developed in collaboration with scientists from eight other institutions. This large acceptance detector is matched to the luminosity and polarized target requirements of the SHR internal target facility.

In the extracted beam mode, the SHR will be used as a pulse stretcher. The basic idea is that the SHR will capture each accelerator beam pulse and then "leak" the electrons to the experiment uniformly between pulses. The technical challenge lies in performing the filling and emptying procedures efficiently, rapidly, and yet smoothly. We anticipate a broad program for example, in exploring nuclear collective motion, in mapping the nuclear spectral function, and in measuring the nuclear pion distribution near threshold.

2. Relativistic Heavy Ions

The Heavy-ion Group is a large part of the E802/E859 collaboration, which has constructed a multi-particle spectrometer that can measure the reaction products produced in collisions induced by the 235 GeV oxygen and 412 GeV silicon beams that have recently become available at the Brookhaven National Laboratory Tandem/AGS accelerator facility (unique in the U. S.). Using these beams, collisions with heavy target nuclei, from aluminum to gold, offer far higher matter/energy densities than heretofore studied, approximating conditions that may have occurred during the initial expansion of the universe. In each central collision hundreds of particles are produced. Analysis of the produced particle multiplicity and transverse energy flow, as a function of target nuclear size, indicates that the projectiles, even at this very high energy, are indeed stopped during central collisions with the largest nuclei, producing energy densities several-fold higher than in normal nuclear matter. Analysis of the spectrometer data has yielded the provocative result that the production of positive strange mesons (K^+) relative to normal π^+ mesons is threefold enhanced compared to proton induced reactions. We are just now analyzing data obtained from the Spring 1991 run that utilizes a newly installed "smart" trigger. By performing particle identification within 10 μ sec this allows on-line event selection, thereby increasing our data sample for K^+ by over a factor of 10. The tracking detector system is being upgraded in order to exploit the much heavier and energetic (2700 GeV) gold beams that will become available when the AGS booster synchrotron is commissioned in 1992, allowing one to reach even higher matter/energy densities. Furthermore, the MIT group has submitted a Letter of Intent, with Prof. Wit Busza as spokesman, for the MARS detector

for the Relativistic Heavy-Ion Collider (RHIC), which is now under construction at Brookhaven. This machine will have almost 40 TeV center-of-mass energy for gold-gold collisions beginning in 1998.

3. Experimental Particle Physics

a. Accelerator Physics Collaboration (APC) Group.

The APC Group is conducting experimental research at Fermi National Accelerator Laboratory (FNAL) in Illinois, the Gran Sasso (GSL) at L'Aquila, Italy, and Brookhaven National Laboratory.

The Group has recently taken data at FNAL in the world's highest energy neutrino beam, utilizing a holographic bubble chamber. This experiment is investigating a new domain in neutrino physics. This experiment is now complete and final papers are in the preparation stage. The Group is now involved in a new Fermi Lab experiment (E-782), which again uses the holographic bubble chamber, to study μ mesons interactions with nucleons. This experiment is now taking in a region inaccessible to other techniques. The data taking stage of this experiment is now complete.

The experiment in GSL, which is the world's largest underground laboratory, will study particle physics and astrophysics problems. The particle physics problems are related to the possibility of a new type of particle being emitted from Cygnus X-3. These studies could confirm emission of such particles and provide information on the mechanisms involved and the properties of the source. This experiment can also search for neutrino oscillations. The Group will also study the production of solar neutrinos and will measure the yearly rate of collapsing stars in the universe. Another objective is the search for point sources in the universe emitting high energy neutrinos.

b. Counter Spark Chamber Group

The Counter Spark Chamber group is continuing the development of the Stanford Large Detector (SLD) at the Stanford Linear Accelerator. The CSC Group constructed the Warm Iron Calorimeter and Muon Detector for SLD. This subsystem was the first completed for the detector and now the rest of the detector is completed and installed in the beam. Currently we are engaged in an engineering run to shake down the detector and the accelerator. The accelerator group is now preparing a polarized electron beam preparatory to an SLD run early in 1992. The CSC Group is looking forward to performing an incisive test of the Standard Model, via the measurement of the difference in the e^+e^- production of fermions with left and right circularly polarized beams. The group continues its involvement in the deep inelastic scattering of muons off nuclei at Fermilab in an effort to understand the formation process of hadrons.

The CSC Group has undertaken three new initiatives directed toward the longer term future, they are:

- 1) Development of a detector for the relativistic heavy ion collider (RHIC) which will be built at BNL by the middle 90's. A proposal has been submitted in collaboration with the heavy ion group and is awaiting action by BNL.
- 2) Participation in the preparation of a proposal for a major detector for Superconducting Super Collider. The group is active and will take a major role in the design and development of the so called 'second detector' for the SSC. This detector is planned to have superior lepton detection capability. In this connection the group has undertaken muon detector research and development.
- 3) The group is participating in the CDF proton- antiproton collider experiment at FNAL in collaboration with the UA1 group (see sec x.-'The Proton- Antiproton Collision Group').

c. Lepton Quark Studies Group

The LQS group is continuing its collaboration on the SLD experiment with the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is presently participating in the commissioning of the experiment and is also involved in the commissioning of the polarized electron beam. With this polarized electron beam, SLD will be able to study production of Z-bosons

with left- and right-handed polarized electrons, allowing tests of the present gauge theory with unprecedented precision. Because of schedule delays and difficulty in attaining SLC design goals, the group is embarking on two other new research projects centered at SLAC, to augment their physics program:

1. A collaboration has been formed between US and Chinese groups to exploit high statistics studies of electron-positron interactions in the 3 to 5 GeV energy region with the Beijing Spectrometer situated at the Beijing Electron Positron Collider (BEPC) at the Institute for High Energy Physics (IHEP) in Beijing; a follow-up of very fruitful experiments carried out at SPEAR, SLAC's former storage ring collider facility, during 1982-89.
2. An e^+e^- international facility operating at SPEAR energy region is being pursued. Known as the Tau-Charm Factory, it will have event rates 100 times and 1000 times more than BEPC and SPEAR, respectively, with a high precision spectrometer, allowing for continued studies of charmed mesons, charmonium states and properties of tau lepton.

d. Electromagnetic Interactions (EMI) Group

Following the six year construction and installation program of the L3 experiment at the LEP accelerator (Large Electron Positron Collider) at the European Organization for Particle Physics Research (CERN) in Geneva, Switzerland, the Electromagnetic Interaction Group (EMI), led by Samuel C.C. Ting, has been taking data since the machine first became operational in the summer of 1989. To date, 33 scientific papers from L3 have been published, including the first publication from LEP. L3 is the largest of the four LEP detectors and is distinct from the other detectors in its design and physics objectives. L3 is an ultra-precise detector built with state-of-the-art technology to study photons, muons and electrons with unprecedented accuracy. Collaborating with the MIT/LNS/EMI group on L3 is an international consortium of 479 physicists from 44 institutes and 13 different countries. It represents the first large-scale high energy physics experiments in which scientists from the United States, the Soviet Union, China, and India work together with the strong support of their respective governments. As in the past twenty-five years, the EMI group continues to bear the leading responsibility for the design, construction, installation, execution, and data analyses of all its experiments.

The LEP machines has been operating at a luminosity of $2 \times 10^{31} \text{c}^{-2} \text{sec}^{-1}$. To date, L3 has collected and analyzed more than 170k Z^0 particles (the carrier of the electroweak force) and with this data sample have been able to carry out many in-depth studies, among which are the following:

- 1) We have measured the mass and width of the Z^0 and were the first group to directly measure the branching ratio of Z^0 into electron and muon pairs. We have found:

The mass of Z:	$M_Z = 91.181 \pm 0.010 \pm 0.02$ (LEP) GeV, and
The total width of Z:	$\Gamma_Z = 2.501 \pm 0.17$ GeV,
The hadron width of Z:	$\Gamma_{\text{had}} = 1.742 \pm 0.019$ GeV.

- 2) In the framework of the Standard Model, our results show that there are only three kinds of neutrinos in the the universe (3.05 ± 0.10).

- 3) We have set limits on the mass of the Top quarks ($M_t = 193_{-69}^{+52} \pm 16$ GeV).

- 4) In the search for new particles, we have set limits on the mass of the charged Higgs and neutral Higgs boson ($M_{H^0} > 41.8$ GeV and $M_{H^\pm} > 36.5$ GeV at 95% c.l.) as well as Supersymmetric particles: scalar muons, scalar electrons, winos, and scalar leptoquarks, as well as New Charged and Neutral Leptons: excited electrons, muons, taus and neutrinos. (In all case, a lower limit > 41 GeV at 95% c.l. has been obtained).

- 5) We have determined that electrons, muons and taus all have a radius smaller than 10^{-17} inches.

6) In the physics of heavy quarks, $B^0 - \bar{B}^0$ mixing and b quark asymmetries have been studied. L3 has uniquely observed the reaction $Z^0 \rightarrow \bar{B}B$ in which B changes to \bar{B} with a probability of X_B . The signature of this phenomena is the observation of two same sign opposite side high- p_{\perp} leptons. Our measurement is 8σ away from $X_B = 0$. We have obtained $X_B = 0.178_{-0.040}^{+0.049}$.

7) The strong coupling constant α_s has been measured ($\alpha_s = 0.115 \pm 0.009$) to second order QCD from energy-energy correlations. We have determined that all quarks have radius smaller than 10^{-17} inches.

8) We have made the most precise measurements to-date on the neutral current vector g_V and axial vector g_A coupling constants and we have found: $\bar{g}_V = 0.046_{-0.012}^{+0.015}$ and $\bar{g}_A = -0.500 \pm 0.003$.

L3 plans to continue to search for new particles and physics phenomena on the frontier of physics research. LEP is planning to double its luminosity in 1991/1992 yielding 10^6 Z^0 's for L3 to analyze in 1991. The luminosity will continue to increase and by 1995, LEP will cross the W^+W^- production threshold (LEP200). It is at these highest LEP luminosities that the unique advantages of the L3 detector in its design, precision performance and physics potential will be fulfilled.

e. The Proton-Antiproton Collision Group

This new group was recently formed to study proton-antiproton collisions at $\sqrt{s} = 2$ TeV. Part of this new group is coming from the UA1 experiment at CERN, the other part comes from the SLD experiment at SLAC. Two LNS groups with common physics interest have joined in a common effort in the CDF Collaboration at Fermi National Laboratory.

The UA1 group has been studying proton-antiproton collisions at the CERN $S\bar{p}pS$ Collider in Geneva Switzerland. The center of mass energy range extended from 200 GeV to 900 GeV. Most of the data were taken at 630 GeV.

They participated in the discovery of the W and Z particles, the intermediate vector bosons of the electron-weak interaction and studied in detail the properties of these new particles. Some of the many other important physics results include:

- light neutrino species counting (< 5.9 , 90% c.l.),
- search for new sequential heavy lepton $m_L > 41 \text{ GeV}/c^2$ (90% c.l.),
- search for new fundamental particles such as new heavy quarks (top-quark: $M_{\text{top}} > 60 \text{ GeV}/c^2$ (95% c.l.), b' quark (fourth generation charge 1/3 quark): $m_{b'} > 43 \text{ GeV}/c^2$ (95% c.l.) etc...).
- study of the production and decay properties of heavy quarks (charm and beauty) led to the observation of weak mixing between the $B^0_{s,d}$ and $\bar{B}^0_{s,d}$ meson states. Such mixing had until then been observed only in the classic $K^0 - \bar{K}^0$ system. The total b-quark production cross section was measured and a search for rare B meson decays was completed.

While the analysis of some of the UA1 data is continuing, this group is planning to pursue its investigations of proton-antiproton collisions at much higher energies: $\sqrt{s} = 1.8$ TeV, at the Fermilab Collider. The next data-taking period should start in the spring of 1992 and last about two years. The physics priority is the search for the top quark. If the Standard Model is valid, the top quark mass should be lower than about $200 \text{ GeV}/c^2$. Most of the range between the present lower limit and $200 \text{ GeV}/c^2$ should be covered in the next few years.

This group has developed expertise in a new type of calorimeter using alternating layers of uranium and a warm organic liquid (tetra-methylpentane known as TMP). MIT has built the most intricate part of such as calorimeter, a position detector mounted behind 3.4 radiation lengths of uranium/TMP, providing a spatial resolution of about 1 mm.

This group is also involved in the development of alternative computer technologies to provide the vast amount of CPU power needed to analyze data. In particular, "farms" of 3081E processors attached to small IBM mainframes have been developed in collaboration with SLAC and CERN. One of these powerful IBM 3070 emulator farms with 7 3081 emulators is now installed at MIT.

Nuclear and Particle Theory Division

The goal of theoretical nuclear physics research at MIT is to understand the structure and interactions of the hadrons, atomic nuclei, and hadronic matter of which our universe is composed. Major research areas include hadronic structure and interactions, QCD and its effects in nuclei, relativistic heavy ion physics, nuclear many-body theory, chaos in nuclei, and electromagnetic, weak, and hadronic probes of nuclei. This research program combines new initiatives in emerging fields with active ongoing efforts in areas in which MIT has traditionally played a leading role. Theoretical research continues to benefit from strong interactions with experimentalists in electromagnetic and relativistic heavy ion physics and contributes significantly to these experimental programs.

Hadronic structure, QCD, and the role of QCD effects in nuclei are primary topics of research, both because of their fundamental significance and the unique resources at the interface between nuclear and particle physics in the Center for Theoretical Physics. A major recent thrust has been the study of confinement, giving rise to a new understanding of confinement in terms of the propagation of quarks in a fluctuating color field. A variety of analytic approaches to QCD are being explored, ranging from classical solutions to mean field and variational calculations. Particular emphasis is being given to systems containing one heavy quark, for which essential simplifications occur. Lattice gauge theory, which provides a unique tool to solve, rather than model or approximate QCD, has recently been exploited to calculate wave functions and quark correlation functions for the pion, rho, and proton which have been compared in detail with bag and Skyrme model results. A major success is the calculation of charge radii for the pion and nucleon in agreement with experiment. Pioneering studies of the use of deep-inelastic lepton scattering as a probe of nucleon and nuclear structure have continued, with particular emphasis on spin-dependent structure functions.

Theoretical investigations in relativistic heavy ion physics at MIT lie at the heart of fundamental explorations of new regimes of hadronic matter underway at Brookhaven and CERN and anticipated for RHIC. Pioneering studies of J/ψ suppression as a possible signature of a quark-gluon plasma have continued, with emphasis on dynamic plasma screening and final state interactions. The propagation of high-energy quarks and gluons in a plasma has been studied to explore the utility of using hard processes to probe quark-gluon plasma formation. A flux tube model of heavy ion collisions developed previously was extended to study dilepton production. The novel idea of using heavy ion collisions to produce Higgs bosons coherently has also been explored.

Nuclear many-body theory provides the foundation for many aspects of nuclear theory, and has thus been an area of continuing interest. A major focus of recent research has been understanding the role of chaos in nuclear physics and the relation between classical and quantum chaos. A coherent state representation has been shown to provide a useful bridge between quantum eigenstates and periodic classical solutions. Efforts have continued to understand the nature of periodic solutions in multi-dimensional classical systems and their implications for quantum chaos and to calculate periodic solutions for physical processes. Path integral techniques, which have previously been used by this group for a wide variety of nuclear many-body problems, have been applied to the nuclear response function and nuclear level densities. The distribution of momentum in deformed nuclei has been studied in models, in mean field theory, and in e^+e^- experiments. Several new approaches are being applied to nuclear many-body theory, including scattering theory and perturbation theory in a time-dependent basis, application of the doorway state method to ground state properties, and the use of light cone techniques.

Electromagnetic probes of nuclei have been a continuing focus of theoretical interest, both because of the unique precision of electromagnetic probes and important new opportunities to exploit coincidence experiments and polarization observables arising from the Bates program and South hall ring project. Measurements of parity violation in nuclei provide a unique window to study fundamental symmetries and explore the parity non-conserving component of the nucleon-nucleon interaction. Important developments include the discovery of enhanced, and thus potentially observable, anapole moments (which are odd under parity but even under time reversal) in specific nuclei, and calculations of the role of isospin mixing and electroweak corrections in nuclear parity violation measurements. Research to exploit the unique capabilities of polarization and coincidence measurements has continued, and the role of nuclear correlations in the nuclear response function is being investigated.

Research in hadronic interactions addresses both the nature of the hadron-hadron interaction, which is essential for understanding the foundation of low-energy nuclear physics, and the use of hadrons and nuclei as probes of nuclear structure. Two-baryon interactions have been studied in the Skyrme model and using a hybrid bag model with external meson fields, with the goal of exploring coupled channel effects and possible exotic resonances. The role of $SU(3)$ symmetry in baryon-baryon scattering has been explored and shown to have strong implications for the existence of Σ hypernuclei. One of the underpinnings of the relativistic phenomenology for nucleon-nucleus scattering has been called into question by the demonstration that the second-order non-relativistic optical potential can explain medium energy polarization observables, and statistical multi-step reaction theory has been applied to deep-inelastic heavy ion scattering.

Much of the vitality of the Center for Theoretical Physics arises from broad interests in general problems in theoretical physics. Thus, the nuclear theory group has also addressed such topics as topological structures, anomalies, and renormalization in field theory, quantum gravity, the electron gas, and solitons.

Research in particle theory at MIT seeks to extend and unify our understanding of the fundamental constituents of matter and the theory which governs them. During this past year, significant advances have been made in the areas of particle phenomenology, cosmology, and the theory of fields and strings, as well as in the more general areas of quantum mechanics and mathematical physics.

Spin dependent structure functions, which specify the distribution of quarks and gluons in a hadron of a specific spin orientation, are expected to become accessible experimentally and are therefore of particular importance in particle phenomenology. In the context of the parton model, it has now been understood how to completely specify the full set of independent information about particle structure that can be obtained from measurements in which spins are polarized transverse to the direction of the incident particle. This understanding is crucial in planning future experiments. There has also been progress in resolving an old conflict between two apparently different ways of describing elastic form factors in relativistic systems: a fundamental description in terms of underlying quark degrees of freedom and effective theory formulated in terms of low-lying excited hadronic states.

In collaboration with members of the nuclear group, a new model has been developed for the description of hadron structure. This model is motivated by the understanding gained from lattice gauge calculations about the dominant role that should be played by the non-perturbative enforcement of the color version of Gauss's law.

This year, investigations at the interface of quantum field theory and cosmology have focussed on the problem of the generation of density perturbations in the early universe. Progress was made in delineating the classes of theories in which quantum creation of topological defects during the inflationary phase of the big bang could contribute to the formation of the observed large-scale structure in the universe. Also, study of a new model of extended inflation has shown that density fluctuations may be generated on long scales in a way which may be more consistent with present observation.

In quantum field theory, a new way of carrying out the ancient task of regularizing and renormalizing divergent Feynman diagrams has been developed. It has the virtue of simplicity and

generality so that the same method can be used for all of the interactions which occur in the standard model. Up to now there has been no such single method which was effective for all interactions.

Understanding the role of topology and quantum symmetry breaking in field theory is an area in which this group has had a long interest and made seminal contributions. Current work has been focussed on field theories in two space dimensions, with particular emphasis on quantum gravity and the theory of the novel vortex-like structures known as *anyons* which are believed to play an important role in physical two-dimensional condensed matter problems .

In the theory of strings, important advances were made this year in the development of a theory which consistently includes both closed and open strings. Subtle problems in the theory of open strings alone were shown to be resolved by unification with the theory of closed strings previously developed here.

Finally, some new contributions have been made in the general development of quantum mechanics. A novel class of bound states has been discovered for particles constrained in channels, and general theorems and possible applications are being explored. A new method of constructing quantum amplitudes by an unconventional functional integral has been derived, and work is in progress to develop this approach as a practical new tool in quantum mechanics.

ROBERT J. BIRGENEAU

Center for Cancer Research

The Center for Cancer Research was established in 1973 to study fundamental biological processes related to the human disease of cancer. The goals of the Center's research can be generally stated as developing an understanding of (1) the genetic basis of cancer, (2) how alterations in cellular processes affect cell growth and behavior, and (3) how the immune system develops and recognizes antigens. These goals are related to the Center's three major research programs: oncogenes and mammalian genetics, cell biology, and immunology. Currently 144 people work in the Center who are distributed among the research laboratories of 10 faculty.

Financial support for research in the Center comes from many sources. However, the core of this support which provides much of the funds for administration, central research facilities (i.e. glass washing facility, specialized laboratories and partial support for new faculty) is a Center core grant from the National Cancer Institute. This grant was renewed in 1990 and its current term extends to April 30, 1995. The Center's success in attracting grant support is a reflection of the overall excellence of the research and educational activities of its faculty members. In addition to the core grant, the Center's faculty have a total of 42 fully funded projects not including over half a million dollars of competitive support in fellowships for postgraduate studies. The Center is currently in the process of renovating 2,253 sq. ft. of space for research in immunology and vertebrate development. This renovation is partially supported by a construction grant from the National Cancer Institute. The Center has an excellent program in immunology with two senior faculty, Drs. Herman Eisen and Susumu Tonegawa, and with plans underway for future appointments which will strengthen the program with an emphasis on the cellular aspects of modern immunology. Advances in modern immunology have direct implications for control of cancer. Immune cells can readily destroy cancer cells and it may be possible to stimulate this process. In regards to vertebrate development, Dr. Nancy Hopkins has initiated a program studying the embryonic development of a vertebrate organism, the zebra fish. This fish matures rapidly and a single female will generate more than 10,000 eggs per month making it the best genetic system of vertebrate organisms. Variants of this fish generate high incidences of tumors. Dr. Hopkins' newly initiated research on this interesting system will be performed in some of the space being currently renovated.

Dr. Richard Hynes will assume the position of Director of the Center for Cancer Research as of July 1, 1991. Dr. Hynes has had a long and distinguished career at MIT and in the Center joining both in 1974. He was promoted to Professor in 1983, in 1985 he assumed the responsibilities of Associate Head of the Department of Biology, and for the past two years he served as Head. The importance of his research was acknowledged by appointment as an Investigator in the Howard Hughes Medical Institute (February 1, 1988). Dr. Hynes is also a fellow of the distinguished Royal Society of London. A critical aspect of human cancer is the change in recognition by tumor cells of the signals which normally control a cell's position in tissue and rate of division. Dr. Hynes has extensively studied the role of a large extracellular matrix protein, fibronectin, in controlling the position and growth rate of normal and tumor cells. More recently, his laboratory has investigated the receptors on the surface of cells which recognize fibronectin and transmit signals to the cell's interior. The structure of these receptors, called the integrin receptor family, varies among different types of cells in the body and between tumor and normal cells. The structural integrity of normal tissue reflects the physical linkage of the extracellular matrix, partially composed of fibronectin, with an intracellular cytoskeleton, partially formed of filaments composed of actin proteins. The integrin receptors and other proteins link these two structural assemblies. This chemical picture of the unity of a cell in its normal place in tissue is one of the major advances in modern cell biology. Dr. Hynes' research has held its lead in these advances.

Honors afforded to the faculty of the Center during this past year were: Dr. Tonegawa received the Order of the Southern Cross from the President of Brazil; Dr. Phillip A. Sharp was elected member of the Philosophical Society and the Institute of Medicine, National Academy of Sciences. Dr. Sharp also received the Dickson Prize from the University of Pittsburgh and he received an honorary degree of Doctor of Humane Letters from Union College, his alma mater.

The faculty of the Center fulfill critical roles in the educational program of the Department of Biology. Our colleague, Dr. Hynes, has served as Head of the Department for two years; Dr. Sharp will assume this position starting July 1, 1991. Dr. Frank Solomon serves as Chairman of the Department's Graduate Program. Both Drs. Hynes and Sharp are involved in the planning of the new biology building now under construction.

In a historical perspective, the past six-year period has been an important transitional period for the Center for Cancer Research. It commenced with Dr. Sharp assuming the Directorship of the Center from Dr. Salvador Luria and the departure from the Center of Professors David Baltimore, Robert Weinberg and Richard Mulligan to the then newly established Whitehead Institute at MIT. Also, during this period of transition, the research programs of the Center grew and evolved. Two Center faculty members were appointed Investigators of the Howard Hughes Medical Institute (Hynes and Tonegawa). Resources from the Center and the Howard Hughes Medical Institute were combined to create state-of-the-art core facilities for analysis of cell populations and synthesis and sequencing of biological polymers. Research space in the Center was expanded and renovated to accommodate the growth in programs of its faculty. Faculty members in the Center played a critical role in developing the Program of Excellence for research in heart disease (Drs. Hynes, Housman and H. Earl Ruley) and the Human Genome Center (Dr. Housman). Both of these multi-investigator research programs complement the Center's research on cancer and greatly strengthen its effectiveness. Furthermore, during this past six years the Center has had an important role in advancing our understanding of human cancer which will ultimately result in more effective therapies. The Center has a strong basis to extend this record of accomplishments and the faculty, research fellows, students, support staff and administration are excited about the opportunity.

The strength of the Center remains its attractiveness as an environment for the training of young scientists. The Center has 40 graduate and undergraduate students and 57 postdoctoral fellows/associates. The Center also benefited from a number of international faculty-rank visitors during the past year: In Dr. Tonegawa's laboratory: Drs. Stefan H. E. Kaufman (Institut für Microbiologie der Universität Ulm, Germany), Werner Haas (Hoffman La Roche Institute, Basel, Switzerland), Antonio Coutinho (Institut Pasteur, Paris, France), Hidde Ploegh (The Netherlands Cancer Institute, Amsterdam, The Netherlands), Charles M. Steinberg (Basel Institute for Immunology, Basel, Switzerland). In Dr. Housman's laboratory: Guenther Heinrich (Sandoz Corporation, Basel, Switzerland), Hiroyuki Aburatani (Tokyo University, Tokyo, Japan), Hiromichi Ishikawa (Keio University, Japan). In Dr. Phillips W. Robbins' laboratory: Drs. Neil Gow (Aberdeen University, Scotland) and Annette Herscovics (McGill University, Montreal, Canada). In Dr. Brent Cochran's laboratory: Maciej Kotecki (Institute of Human Genetics, Poznan, Poland). In addition, a number of physicians who have affiliations with teaching hospitals in the Boston area are in training in the various laboratories of the Center: Drs. Barbara Shephard and Cynthia Kellogg, Tufts New England Medical Center; Drs. David Fisher, and Daniel Haber, Fellows in Medical Oncology, Harvard Medical School and the Dana Farber Institute; Dr. David Potter, Hematology Fellow, Brigham & Women's Hospital and Harvard Medical School; Dr. Michael Rabin, Beth Israel.

PHILLIP A. SHARP
Director

Center for Space Research

THE CENTER FOR SPACE RESEARCH (CSR) conducts an active program of research in astronomy, space science, and related technology, with emphasis on experimental and theoretical investigations in support of various National Aeronautical and Space Administration (NASA) flight missions. Although the primary source of support comes from NASA, a significant fraction of the research program is sponsored by the National Science Foundation (NSF) and the Department of Defense (DOD). Specific areas of research include gravity-wave, X-ray, optical, radio, and radar astronomy; geodesy; theoretical and experimental space plasma physics; planetary surfaces and atmospheres; and the life sciences. The current and near-future NASA flight program contains a number of missions in which CSR is heavily involved: the Voyager-1 and 2 mission to the outer planets, the Magellan Venus Radar Mapper mission, the Cosmic Background Explorer (COBE), the Advanced X-ray Astrophysics Facility (AXAF), the X-ray Timing Explorer (XTE), the Space Transportation System (Shuttle) Spacelab series, and an investigation of Earth's plasma environment as part of the International Solar Terrestrial Physics Program (ISTP). Two other "mission-of-opportunity" programs, in which CSR is playing a crucial role, are ASTRO-D, a Japanese X-ray satellite for which CSR is supplying an imaging detector, and the High-Energy-Transient Experiment (HETE), a small, inexpensive satellite under MIT's direct control. CSR also supports a program of theoretical astrophysics and of optical observations carried out at the Michigan-Dartmouth-MIT (MDM) Observatory (whose operations are partially managed by CSR as MIT's agent). An overview of CSR activities during the past year follows; all faculty are in the Physics Department unless otherwise noted (AA refers to the Department of Aeronautics and Astronautics; EAPS to the Department of Earth, Atmospheric, and Planetary Sciences; EECS to the Department of Electrical Engineering and Computer Sciences).

RESEARCH IN X-RAY ASTRONOMY

Analysis of Data from Satellite X-ray Observatories. The MIT X-ray group has continued its observational program using the Japanese satellite GINGA, as well as the archives of data from previous US and European X-ray missions. Data are just now becoming available from the German ROSAT mission, launched in May of 1990.

Professor Hale Bradt, Dr. Ronald Remillard and students continue to study x-ray sources in their recently completed 660-source catalog of identified HEAO-1 sources with emphasis on the global multiwavelength properties of active galactic nuclei (AGN) and cataclysmic variables. Data from many satellites are being used for this purpose, e.g. IRAS, Ginga, and ROSAT. Individual objects include an irregularly varying cataclysmic variable with an asynchronous spin-orbit rotation which places it in a unique evolutionary state. Bradt and Remillard have recently become members of the ROSAT Galactic Plane Survey team, and are actively carrying out optical identifications of these objects at the MDM observatory. More than 100 out of 148 sources have already been identified to be stars with active coronae, AGN etc. Professor Claude Canizares and his colleagues have just completed a catalog of X-ray spectra from the Einstein Observatory (HEAO-2) spectrometer. Specific studies of the spectra of supernova remnants and active galaxies are also being pursued, including a supernova remnant in the Large Magellanic Cloud found to be extremely rich in oxygen. Canizares and Professor Paul Schechter and student are observing elliptical galaxies with ROSAT in an attempt to determine the shape of their gravitational potentials. Professor Walter Lewin and his graduate student are making optical observations of the galaxy M31 in preparation of their 200 ksec ROSAT observations of M31 which will be made in July this year. The M31 ROSAT observations are made in collaboration with scientists from Germany and Holland. Lewin has been studying low-mass X-ray binaries using the Japanese observatory GINGA and using archival data from the European observatory EXOSAT. Together with his Japanese and Dutch collaborators, Lewin has made major advances in the relation between the radio emission of bright low-mass X-ray binaries and their X-ray emission. Lewin has instigated a program of simultaneous Ginga/ROSAT observations which cover an energy range from about 0.1 keV - 20 keV which is an unprecedented range. These observations will continue on selected sources as long as Ginga is alive (its reentry is expected within 6 months). Professors George Clark and Saul Rappaport and their students, working in collaboration with colleagues at the Institute of Space and Aeronautical Sciences (ISAS) in Tokyo, continue studying the atmospheric and wind structures of the companion stars of X-ray pulsars using GINGA. Dr George Ricker and his students are carrying out an extensive X-ray study of gamma ray burst sources with the ROSAT satellite in an attempt to identify the origin of these mysterious sources.

Advanced X-ray Astrophysics Facility (AXAF). AXAF is a major NASA mission of the "great observatory" series, scheduled for launch in 1998. Two of the three instruments for this mission being designed at MIT, the High-Energy Transmission Grating Spectrometer (HETG) and the AXAF Charge-Coupled Device (CCD) Imaging Spectrometer (ACIS), have been approved for flight on AXAF as "core instruments" and are now being developed under contract. The third, the Bragg Crystal Spectrometer (BCS), has been continued in its definition phase for possible approval next year.

The HETG represents a collaboration of Professor Canizares and his group at CSR with Professor Henry I. Smith (EECS) and his Submicron Structures Laboratory. The group continues to develop techniques for fabricating large numbers of 0.2- μm -period gratings having very high uniformity. BCS definition, under Professor Canizares, has focused on simplification of the instrument and development of ultra-thin, low-leak-rate detector windows. Aluminum coated polyimide windows have been developed with leak rates at least 100 times lower than previous materials. A group under Dr. George Ricker (CSR), Deputy Principal Investigator for ACIS, has continued collaboration with the Micro-Electronics group of the MIT Lincoln Laboratory to develop radiation-hardened X-ray CCDs having quantum efficiencies of better than 50 percent over the 2- to 6-keV energy range. Noise levels equivalent to the effects of fewer than 2 electrons allow a spectral resolution of better than 120 eV (full width at half maximum) to be achieved at 6 keV, and permit low energy response extending to below 0.5 keV.

ASTRO-D Mission. This program is a joint undertaking of CSR (through NASA) and ISAS (in Japan). Under the terms of the international agreement, CSR is providing a focal-plane instrument incorporating two arrays of ultra-low-noise CCD X-ray detectors, for launch on a Mu-3-SII rocket by ISAS from Kagoshima Space Center in Japan in February 1993. Dr. Ricker is the Principal Investigator for the ASTRO-D CCD instrument and, as in the AXAF mission, Lincoln Laboratory is participating with CSR in the design and fabrication of the CCD sensors. Following launch of ASTRO-D in February 1993, members of the X-ray astronomy group at MIT will join with the ISAS team in carrying out and analyzing observations of cosmic X-ray sources using ASTRO-D. The flight unit is under construction and is scheduled to be delivered to Japan during this year.

High Energy Transient Experiment (HETE). HETE is a low-cost "mission-of-opportunity" concept developed by Dr. Ricker and his group and now accepted by NASA for launch in July 1994. The HETE consortium includes scientists from Los Alamos National Laboratory, the University of Chicago, CNES/CESR (Toulouse, France), the University of California (Berkeley and Santa Cruz), and RIKEN (Japan). HETE will search for bright transient emissions from astronomical objects over a very broad energy interval extending from the ultraviolet to gamma rays. The primary objective of HETE is to reveal the basic nature of enigmatic celestial gamma-ray bursts by determining their precise locations and broad-band spectral properties, and to probe the underlying physics of the emission which takes place under extreme values of temperature, density, and magnetic field. The HETE instruments will be mounted on a novel "mini-spacecraft", which will be dropped from a high altitude jet aircraft and injected into low earth-orbit using the Pegasus launch system. Because of the small mass of HETE (approximately 100 kg for the spacecraft and its instruments), and its use of low cost management, development, and launch techniques, it is being referred to as a "Cheapsat." MIT and its collaborators have commenced the design of HETE and are preparing to move into the detailed design and fabrication phase in December 1991 under a "fly-to-cost" contract with NASA.

X-ray Timing Explorer (XTE). This X-ray astronomy satellite is scheduled for launch in 1996. It will study the time variability of celestial X-ray sources at time scales ranging from tens of microseconds to years over energies of 2-100 keV. A group under Professor Bradt is responsible for one of the three experiments on XTE, namely the All-Sky Monitor (ASM) that will be used to detect the appearance of new X-ray sources or changes in the intensity of existing sources. MIT is also responsible for a complex on-board data system that will accommodate the high data rates expected from the large-area detectors. The design effort is well underway.

Explosive Transient Camera (ETC). This MIT facility, colocated with the MDM Observatory on Kitt Peak (see next item), is designed to search the entire night sky for brief flashes of light suspected to be emitted concurrently with high-energy gamma-ray burst events. Fully automated operation of a test array began in May, 1987, under the supervision of Drs. Ricker and Vanderspek, including remote command and data retrieval over Internet from the MIT campus. In November 1990, a full array of 16 camera units commenced routine operations. Currently the ETC is carrying out coordinated observations of gamma-ray burst events detected by NASA's new Gamma Ray Observatory (GRO) launched in April, 1991. This activity will continue over the next 3-4 years.

THE MICHIGAN-DARTMOUTH-MIT (MDM) OBSERVATORY

The Michigan-Dartmouth-MIT Observatory, located on Kitt Peak near Tucson, Arizona, is comprised of two separate telescopes 1.3 and 2.4 m in diameter, and is operated jointly by the University of Michigan, Dartmouth College and MIT (CSR).

Following tests indicating that the primary mirror of the 2.4 m produced unsatisfactory images, the mirror was removed from the telescope and shipped to Pittsburg for refiguring by Contraves USA. The mirror was reinstalled in March 1991. On nights of good seeing the telescope now produces images of 0.8 arcsecond diameter. Efforts are underway to control the

thermal environment at the 2.4 m telescope dome to see if further improvements in the image quality may be had. The 1.3 m telescope continued to be oversubscribed during the past year.

Much of the work at MDM this year involved searches for the optical counterparts of stars, nebulae, galaxies and clusters of galaxies discovered at other wavelengths. Professor Bradt, Dr. Remillard and students obtained spectroscopy and photometry of cataclysmic variable stars identified in the HEAO-1 hard X-ray survey. Dr. Remillard obtained spectra of stellar sources identified by the recently launched ROSAT X-ray satellite. Professor Lewin and student Magnier have produced mosaic digital images of the nearby Andromeda galaxy for use in identifying new X-ray sources identified by the ROSAT satellite. Dr. Bautz has searched for evidence of star formation in galaxies thought to be the "sinks" in X-ray cooling flows. Professor Kistiakowsky is searching for optical counterparts to supernova remnants identified at radio wavelengths. Drs. Ricker and Vanderspeck are working to identify optical counterparts to candidate gamma ray burst sources found with ROSAT.

Professor Binzel (EAPS) has continued his photometric comparative study of near-Earth and small main-belt asteroids. Professor Tonry and student Moore are determining distances to elliptical galaxies using surface brightness fluctuations. Tonry's student observed nearby globular clusters to help calibrate the surface brightness fluctuation method. Professor P. Schechter and collaborators are continuing their study of the structure of the Milky Way using carbon stars and Cepheid variables. More details on the optical astronomy research program are given in the report of the Astrophysics Division of the Physics Department.

RESEARCH IN SPACE PLASMA PHYSICS

Interplanetary and Magnetospheric Plasmas. Professor John Belcher and Dr. Alan Lazarus, continue to study the properties of solar wind plasma at 35 AU from the Sun using Voyager 2. Currently the group receives data from 35 AU one day after it arrives at Earth. The Plasma Group is developing software to adjust to the new data configurations at JPL. There are JPL planning sessions in process which will specify the shifts in data acquisition and tracking coverage if the crossing of the terminal shock is thought to be imminent, as well as defining how that determination will be made. There has been in the last month a tremendous amount of activity in the outer solar system as a result of the recent large number of solar flares. The group is seeing phenomena at 35 AU which have never been seen before in the inner solar system--two beams of protons, of equal density, separated by 100 km/sec in speed. The origin of these beams is presently unknown, but it is clear from such measurements that the cruise to the terminal shock will be far from uneventful.

Work continues on MIT's contribution to the plasma instrumentation (looking at the solar wind) for the WIND spacecraft, due to be launched in late 1992. The spacecraft's orbit will allow it to spend two years exploring the region between Earth and a position about 100 earth radii in the direction of the sun. After this time the spacecraft will be "stationed" in this region to supply data on incoming solar plasma to a fleet of spacecraft exploring regions closer to Earth in a coordinated effort termed Global Geospace Science. In the next few months we shall deliver the flight solar wind sensors for the WIND spacecraft. The engineering model sensor and its accompanying electronics package (built at Boston University) successfully passed vibration testing and production of flight hardware is now underway. Currently, the MIT solar wind experiment on the IMP-8 satellite is the primary source of data concerning the incoming solar wind; it has been in operation since 1973, and will be replaced by the new activity.

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Theoretical Geoplasma Physics. Activities of the Center of Excellence in Theoretical Geoplasma Research, sponsored by the Air Force Office of Scientific Research under its University Research Initiative, have continued under the leadership of Dr. Tom Chang (CSR), with participation by Professors Belcher and Stanislaw Olbert, and Drs. Geoffrey Chew, David Tetreault, and Fareed Yasseen. The Center, contained within CSR, is designed to foster research on the theory of plasma phenomena occurring in the terrestrial ionosphere and magnetosphere. A number of prominent international scientists, as well as postdoctoral research fellows, have spent time at MIT during the past year, and participated in a variety of workshops and symposia organized under this program. Support for the Center has broadened in the last year to include contributions from the Air Force Geophysical Laboratory, NASA, Lockheed Aircraft's Research and Development Division, and the Applied Physics Laboratory of Johns Hopkins University.

PLANETARY STUDIES

Magellan Venus Radar Mapper Mission (MGN). This mission, designed to map the entire surface of Venus at a resolution approaching 100 m using synthetic aperture radar (SAR) techniques, arrived at Venus on August 10, 1990 and has completed its first 8-month cycle of observation (corresponding to one full rotation of Venus under Magellan's orbital plane). Professor Gordon Pettengill is the Principal Investigator for the radar portion of this mission, with support from Professor Sean Solomon (EAPS) and Drs. Joseph Binsack and Peter Ford. Although the SAR data reduction and image production is being carried out at NASA's Jet Propulsion Laboratory, CSR has responsibility for analyzing the ancillary altimetric and radiometric data and for presenting the results as images and digital data sets. As part of this effort, an MGN-dedicated digital processing laboratory has been set up in CSR. It is expected that this mission will operate for at least the next five years.

Mars Observer Mission (MO). Professors Pettengill and Solomon are also involved in an experiment using a laser altimeter to determine the surface relief of Mars at a lateral surface resolution of 160 meters, and with a vertical accuracy of several meters. This instrument, developed at Goddard Space Flight Center, has been delivered to the spacecraft manufacturer for integration and will be placed in orbit around Mars by the MO spacecraft in the fall of 1993.

SPACE GEODESY

Professor Counselman and colleagues are developing a system to monitor strain accumulation in the crust of the earth regionally and globally. Radio signals from tiny transmitters distributed throughout areas being monitored are relayed by satellites to central processors which determine the positions of the transmitters from the phases of the signals. Tens of thousands of points (e.g. distributed throughout Japan and the state of California to form an earthquake warning system) may be monitored continuously and simultaneously. Proof-of-concept experiments using phase measurements of similar signals transmitted by satellites and received at the monitored earth-surface points have yielded daily strain-measurement precision of 1 part in 50 Million.

RADIO ASTRONOMY

A number of approaches have been taken to enable the placing of satellites in space that can serve as radio telescopes, synchronized with the world-wide network of telescopes on the ground. The combined array allows one to map radio sources with an angular resolution far greater than that achievable from ground arrays alone. Two missions are planned at present: RADIOASTRON, a Soviet mission, and VSOP, a Japanese mission. Both missions are proceeding, with the Soviets currently planning a late 1994 launch, and the Japanese planning for a February 1995 launch. The MIT activities lead by Professor Bernard Burke have been focused on technical support and mission planning support for these missions. No US mission is currently planned, but advanced planning is started on the formulation of US activities in this area.

The technical means for the discovery of planets orbiting other stars and for studying the physical characteristics of such systems have advanced greatly in recent years. There are immediate approaches that can be taken that concentrate on indirect detection. Eventually, however, it should be possible to detect such exoplanets (a recommended term for planets belonging to other solar systems) by direct means. One approach, requiring long-range planning, would be to design such a system for emplacement on the moon. A study of these possibilities has been published. In the meantime, NASA has formed a science working group to lay out an orderly program for developing missions, both in the near-term and some years into the future, with Burke as chairman. Professor Burke also continues as Principal Investigator of the US team participating in the NASA project to establish a VLBI station in Earth orbit (formerly known as QUASAT), now envisaged for realization in association with Japan, or possibly the Soviets, in the mid 1990's.

COSMOLOGY AND GRAVITATION RESEARCH

Gravitational Wave Research. The Laser-Interferometer Gravitational Wave Observatory (LIGO), a joint project of Caltech and MIT to develop and construct two 4km baseline gravitational wave interferometers in the continental United States to operate in concert with interferometers in Europe, continues research and development. The intent of the project is to detect gravitational waves originating from astrophysical sources. Current research has been dedicated to improving the performance of a 40 meter prototype at Caltech, demonstration of interferometric techniques applicable to the large scale

system, and improvements in ground noise isolation and reduction in the influence of thermal noise. The project has made a public solicitation of site proposals and received 19 proposals from 18 states. Full funding for LIGO is still pending Congressional approval. The project is directed by Professor Rochus Vogt of Caltech and the principals at MIT are Professor Rainer Weiss and Dr. David Shoemaker.

Cosmology Research. The Cosmic Background Explorer (COBE) Mission continues to take data on the anisotropy of the CBR on angular scales 7 degrees and larger at 30, 50 and 90 GHz and maps the sky in four bands between 1 and 5 microns. This instrument does not require liquid He cryogenics, so it continues to function despite the expiration of on-board He supply. These observations have yielded upper limits to the quadrupole moment of the microwave background and the Comptonization parameter.

The MIT balloon-borne radiometer operating as a survey instrument with a 3.5 degree beam has mapped about 1/3 of the sky in four spectral bands near 1 mm wavelength. The measurements measure the anisotropy in the cosmic microwave background radiation as well as mapping the Galaxy in the sub-millimeter band. The data have been used to test for limits on anisotropy for both Gaussian shaped correlation functions and power law correlation functions. These data place the most stringent limits on models for large-scale structure growth of any to date and on any angular scale.

AEROSPACE PHYSIOLOGY AND MAN-MACHINE SYSTEMS

Prof. Laurence R. Young (A&A), assisted by Dr. Charles M. Oman (A&A), and their colleagues in the Man-Vehicle Laboratory (MVL) have spent the 1990-91 academic year preparing for several spaceflight opportunities scheduled during the 1991-1992 time frame. The successful flight of SLS-1 (June 1991) culminated 9 years of work by the MVL and the Laboratory for Space Experiments (LSE). The year saw most of the laboratory involved in the pre and post-flight testing associated with this mission, affording the graduate students the opportunity of working directly with the astronauts. Dr. Dan Merfeld, a former graduate student, joined the staff as "Spacelab" Research Scientist. The Laboratory is also involved in two experiments scheduled to fly on IML-1 (in late 1991 or early 1992): Dr. Oman is flying a more controlled version of his 'nystagmus dumping' experiment as part of a concerted series of vestibular experiments, while Prof. Sandy Alexander's Mental Workload and Performance Experiment (MWPE) is also being flown on this flight. Pre-flight activities and crew training have been on-going activities during 1991.

The MVL activity in expert systems ([PI] = "PI in a box") concluded a successful checkout as a ground-based system on SLS-1. Work is being carried on in an effort to have this system included as a part of the dome flight objective for SLS-2.

THEORETICAL ASTROPHYSICS

Several faculty associated with the Center for Space Research carry out research programs in theoretical astrophysics. Topics include cosmology and the inflationary universe scenario, the large scale structure of the universe, galaxy formation, studies of cooling flows in clusters of galaxies, star formation, binary star evolution, physics of active galactic nuclei, and other topics. Details of this research are presented in the report of the Astrophysics Division of the Physics Department.

CLAUDE R. CANIZARES

Experimental Study Group

The Experimental Study Group (ESG) finished its second year at MIT under the direction of Professor Vernon M. Ingram from MIT's Department of Biology. ESG began in 1968 and is the oldest alternative freshman program at MIT. It continues to attract a great deal of interest from incoming students, primarily because its flexible structure can accommodate the educational needs of a variety of students.

STUDENT STATISTICS

ESG enrolled 83 students this year for one or more terms in its core curriculum in chemistry, biology, physics, mathematics, humanities, and social sciences - 53 freshmen, 4 sophomore transfers, and 26 ESG upperclassmen. This is the highest figure in the history of the program. In addition, 17 MIT freshmen applied to ESG in the fall and were not accepted due to overcrowding. The breakdown by term of enrolled students (including non-ESG students attending ESG seminars) is as follows:

	Fall 1990	Spring 1991
Freshmen	47	40
Sophomore transfers	3	1
Upperclassmen who were in ESG	15	17
Non-ESG upperclassmen in ESG seminars	23	31
Total enrollment	88	89

Forty-five percent of ESG's freshman class for the year were female and nine percent were minorities (including two Navajo Indians). Twenty-one percent of ESG's freshmen were international students, from countries as diverse as Gambia, Indonesia, Kuwait, Turkey, and Bangladesh.

The 53 sophomores currently registered at MIT who had been in ESG as freshmen earned a cumulative median grade point of 4.3 this spring, compared with a figure of 4.1 for the entire MIT sophomore class. Approximately half of our sophomores are majoring in the School of Engineering and a third in the School of Science, compared to the Institute average of two-thirds of all undergraduates being enrolled in the School of Engineering.

ADMINISTRATION

Professor Ingram, Director of ESG, and Holly Sweet, Associate Director, oversaw the administration of the program in consultation with the ESG Advisory Committee. The committee is chaired by Professor Alan Davison (Department of Chemistry), and includes representatives from the Departments of Mathematics (Professor Alar Toomre who replaced Professor David Anick in the fall), Physics (Professor Lee Grodzins), History (Professor Arthur Kaledin), and the

Dean of the School of Science (Professor Gene Brown). Along with their administrative roles at ESG, both Professor Ingram and Ms. Sweet taught in ESG. Ms. Sweet will be taking a one year leave of absence in the fall to do a clinical internship for her doctoral program in counseling psychology. A graduate from the ESG program, Andrea McGimsey '87, will be serving as Assistant Director in Ms. Sweet's absence.

STAFF AND FACULTY

The ESG staff retained a great deal of continuity from last year, with five staff members returning who have been teaching at ESG for at least seven years. The physics staff included Professor Emeritus Robert Halfman, Dr. Peter Dourmashkin, Craig Watkins, and David Custer '82 and Sen-Ben Liao '90, both ESG alumni. The mathematics staff was headed by Dr. Jiang-hua Lu and included graduate students Eric Babson, Eitan Bachmat, David Cape, Daniel Edidin, Paul Gunnells, and Richard Ehrenborg.

In the fall term the chemistry staff was headed by Melanie Holland '90, an ESG alumna who taught 5.11 Principles of Chemical Science and an ESG recitation section of 5.12 Organic Chemistry. She was assisted by Michael Brody '91 and graduate student Todd Anderson. Mr. Anderson replaced her as the head of our chemistry staff in the spring term. Professor Ingram taught SP01 and SP02 Chemistry, Materials Science, and Biology in the regular curriculum. An ESG recitation section was run by Ms. Holland in the fall and by Corinne Olesen (a graduate student in the Biology Department) in the spring.

Our chemistry, physics, and mathematics staff were assisted by 29 undergraduate tutors (most of whom had been in ESG as freshmen). These tutors shouldered a good portion of ESG's teaching load at ESG, yet managed to maintain a 4.5 cumulative grade point average. One of our tutors, Will Glass '92, won a Stewart award this spring for his work with the MIT Educational Studies Program administering the teaching of over 400 local high school students. We consider our undergraduate tutors to be one of ESG's finest assets and indispensable to the successful operation of our program.

ESG also offered several HASS-D and HASS classes to its students. Dr. Lee Perlman taught two courses in political science and philosophy, and Mr. Custer taught both expository and creative writing. Dr. Perlman has been offered an assistant professorship in political science at Swarthmore College in the fall so will be leaving ESG after eight years as an instructor in our program. We will miss his commitment to teaching and wish him the best in his new position.

Several of our staff members have been actively involved in other programs around the Institute in addition to their work in ESG. Dr. Dourmashkin taught physics in the Office of Minority Education's Project Interphase and XL programs, and in the Integrated Studies Program. He also helped teach a recitation section of 8.01x and 8.02x for the Physics Department. Ms. Sweet was involved for her fourth year in the Freshman Interview Project, sponsored by the Office of Undergraduate Education. She also ran several workshops during the year on career development and personal growth for various

organizations around MIT, including the Women's Forum, the Working Group on Support Staff Issues, and the Office of Dean for Student Affairs. We consider the connection of our staff members with other areas at the Institute a fertile ground for the development of new ideas in teaching and learning.

ACADEMIC DEVELOPMENTS

For several years ESG has been offering undergraduate and freshman advisor seminars, both for ESG students and for students in the regular curriculum. This year we offered a variety of seminars in physics, biology, sociology, and political science which attracted a total of 71 students.

Dr. Perlman and Ms. Sweet co-taught SEM051 Sex Roles and Relationships both terms, a course which has become increasingly popular since it was first offered at MIT through ESG's sponsorship in 1985. This year it was oversubscribed by at least 15 students each term. Dr. Perlman also offered SEM065 Non-Violent Political Action to 14 students.

Professor Ingram developed a new advisor seminar, SEM017 Computer Modeling in Biology, which he offered to his ESG advisees in the fall. He developed a mini-version of this course (called MacBio) which he offered for three units of credit to six students during IAP91. Dr. Dourmashkin taught a seminar on the Archaeology of Natural Sciences to six ESG students, a seminar which one student described as "perhaps the most valuable academic experience I've had."

Two of our tutors, Mr. Glass and Chris Hoadley '91, were involved in organizing an introductory non-credit bearing course on computer science which was offered both in the fall and during IAP91 to ESG and ISP students. Because of the amount of interest the subject generated, it will be offered again this coming year.

For the first time in its history, ESG sponsored a prize for the best independently conceived and executed study project developed by an ESG freshman (or a currently enrolled MIT student who was in ESG as a freshman). The award of \$500 was funded by a contribution from ESG alumnus Dr. Kalle Kang '74. Two ESG students jointly won this prize. Nicholas Cassimatis '94 wrote an extended paper on the use of language as a sociological phenomenon. David Harris '94 used his computer game "Robotalk" to observe how local junior high and high school students learned how to evolve a program for robots. Judging of the papers and projects was done by Professor Ingram in conjunction with faculty members in departments related to the projects being submitted.

ESG continues to provide a home for students and staff at MIT who are interested in a more individualized and experimental approach to education. We applaud the efforts of all of our community members who have contributed in their own ways in maintaining ESG as a valuable Institute resource for curricular and social innovation.

VERNON M. INGRAM
HOLLY B. SWEET

George Russell Harrison Spectroscopy Laboratory

The George Russell Harrison Spectroscopy Laboratory is engaged in research in the field of modern optics and spectroscopy for the purpose of furthering fundamental knowledge of atoms and molecules and pursuing advanced engineering and biomedical applications. Techniques include the use of lasers and modern optics, microcomputers and other data acquisition systems.

The Laboratory is directed by Professor Michael S. Feld of the Department of Physics. Professor Jeffrey I. Steinfeld of the Department of Chemistry and Dr. Ramachandra R. Dasari, Principal Research Scientist in the Laboratory, are Assistant Directors.

Professors Michael S. Feld, Robert W. Field, Keith A. Nelson, Stephen J. Lippard, Jeffrey I. Steinfeld, Toyochi Tanaka, Mark S. Wrighton, and Drs. Ramachandra R. Dasari and Richard P. Rava are core investigators of the Laboratory.

An Interdepartmental Laboratory, the Spectroscopy Laboratory encourages participation and collaboration among researchers in various disciplines of science and engineering. Research contributors this past year were from several MIT departments, including Chemistry, Physics, Biology, Electrical Engineering and Computer Science, Mechanical Engineering and Applied Biological Sciences. There were also numerous collaborations with outside academic institutions, many of an interdisciplinary nature, as well as with government, industrial and medical organizations.

This past year was one of continued growth. A new grant from NIH to study 'Real time *in vivo* Diagnosis of Dysplasia by Fluorescence' was received. Several new facilities were set up. A new pulsed Ti: Sapphire laser pumped by an Nd:YAG laser was set up in the pulsed visible/UV spectroscopy and kinetics laboratory. A stopped-flow kinetic apparatus was installed in the CW Raman facility. A Satori femtosecond dye laser was purchased as part of the development of the picosecond / femtosecond laboratory.

Prof. Kleppner was awarded the William F. Meggers Prize of the Optical Society of America for research in spectroscopy and precision measurements. Dr. Richard P. Rava was promoted to the rank of Principal Research Scientist. Two new staff members Drs. Ramasamy Manoharan and Kuldip Singh were appointed.

MIT LASER BIOMEDICAL RESEARCH CENTER

The MIT Laser Biomedical Research Center (LBRC) is now in its sixth year of operation as a Biotechnology Resource Center of the National Institutes of Health. Biomedical applications of lasers and laser spectroscopy promise to change the face of medicine as it is currently practiced. The LBRC's charter is to develop the scientific understanding required for advanced clinical applications of lasers. LBRC activities can be grouped into four categories: Laser ablation and propagation of light in tissue; spectroscopic properties of cells and tissue; laser spectroscopic imaging; and laser welding and mediation of the healing process. In addition to core research, collaborative and outside research projects are conducted at the Center. Resources of the Center are provided free of charge, on a time-shared basis, to medical researchers who wish to pursue research in this important new field.

The NSF Regional Instrumentation facility grant is replaced with a new NSF grant 'MIT laser collaborative research facility'. New laboratories and new equipment have been added to facilitate the programs of the NIH, NSF and Industry grants. Currently, there are over 40 major laser systems. Equipment and facilities include continuous wave (CW) and pulsed dye lasers pumped by ion lasers, excimer lasers and Nd:YAG lasers; a pulsed Ti: Sapphire laser pumped by Nd:YAG laser; a tunable laser facility which provides intense pulses of light continuously tunable over the wavelength range 216-4500 nm; a picosecond/femtosecond dye laser facility along with a single photon counting detection system; an infrared diode laser spectrometer tunable in the 3-30 μ m wavelength region; UV and visible resonance Raman facilities; stopped flow kinetic apparatus; nanosecond transient absorption system; FT-IR and FT-Raman spectrometer; equipment for performing spectrally resolved fluorescence microscopy and fluorescence lifetime studies; and computer interfaced absorption and fluorescence spectrophotometers. All laser systems are interfaced with microcomputers which control experiments and collect and analyze data. Auxiliary equipment includes transient digitizers, fluorescence microscopes and several optical multichannel spectral detectors.

RESEARCH HIGHLIGHTS

Professor Steinfeld has been making use of the Titanium-Sapphire laser recently installed in the Harrison Spectroscopy Laboratory to carry out infrared double-resonance spectroscopic measurements on high overtone levels of methane. The information on energy levels, line intensities, linewidths, and collisional relaxation in these levels, gained from such experiments, is needed for interpretation of spectroscopic remote-sensing measurements of objects in the Solar System such as Jupiter, Saturn, and Titan. The experiments are being carried out by Dr. Stephen Coy, a long-time associate of the Harrison Laboratory, and Dr. Bernd Abel, a postdoctoral fellow of the Deutsche Forschungsgemeinschaft.

Professors Robert W. Field and Robert J. Silbey and Postdoctoral Associate Dr. Xinsheng Zhao of the Department of Chemistry continue their experimental study of the dissociation dynamics of the formyl radical (HCO) by SEP. This work pushes the assumptions of statistical reaction rate theory to the quasi-stationary state limit at an energy where the density of states is low enough to permit spectroscopic assignment of individual scattering resonances. In their prior work, HCO was produced by 308 nm excimer laser photolysis of acetaldehyde, but they have recently demonstrated HCO production *via* 266 nm Nd:YAG photolysis. A detailed rotational analysis of B state fluorescence excitation spectra proves that the so-called C state is actually the CH stretch of the B state. This proves that the B state provides Franck-Condon access to all three normal modes [states are labelled (C-H stretch, C-O stretch, bend)] of the ground state of HCO, so that a systematic search for mode-selective chemistry is possible. Taking account of power broadening, measurement of the widths of SEP transitions shows that the (0,4,1) resonance at $8,478\text{ cm}^{-1}$ has a lifetime of 0.88 ps while the *higher* energy (0,5,0) resonance at $9,091\text{ cm}^{-1}$ has a *longer* lifetime of 5.7 ps.

Professors Field and Silbey's studies of vibrational dynamics on the ground electronic surface of acetylene (HCCH) have made great progress in the last year. A collaboration with Dr. Kaoru Yamanouchi, of the University of Tokyo (Japan) partially elucidated the short time (30 fs to 2 ps) dynamics of acetylene by a comparison of low resolution Dispersed Fluorescence (DF) to high resolution SEP spectra of HCCH in the ground state. The features of the DF spectra (which are not eigenstates, but can nevertheless be assigned) are mainly composed of progressions in the ν_2 (C-C stretch) and ν_4 (*trans*-bending) modes. A notable feature of this analysis was the tentative identification of a resonance between ν_4 and ν_5 features occurring exactly at the positions calculated for the *eigenstates* from a high resolution infrared spectroscopic analysis $6,000\text{ cm}^{-1}$ lower in energy. At moderate energy, this resonance produces a second set of two progressions in the ν_2 and ν_4 modes built on two quanta of the *cis*-bend (ν_5). 60% of the vibrational bright states between $5,700$ and $23,400\text{ cm}^{-1}$ could be assigned to these progressions. This tentative analysis has been dramatically confirmed in SEP experiments conducted this past year. These experiments also prove the importance of the Fermi resonance $(\nu_2 + \nu_4 + \nu_5)^0 - \nu_3$. This is the first evidence for the anti-symmetric stretch (ν_3) in the SEP spectrum, and opens up a key pathway for intramolecular vibrational relaxation (IVR). This IVR pathway may explain the anomalously high density of states and signatures of chaos in the high energy SEP spectrum.

Professors Field and Silbey continue the new experimental study of excited electronic states of the iso-electronic molecules acetylene (HCCH) and hydrogen cyanide (HCN) begun last year. In HCN, the dipole moment of the first excited singlet state has been measured from the Stark effect on the vacuum ultraviolet $A(010)^1 \leftarrow X(00^0)$ fluorescence excitation spectrum to be $0.92 \pm 0.04\text{ D}$, in quantitative agreement with a recent *ab initio* calculation. UV-optical double resonance studies of the A state of DCCD using the C' state discovered previously in this laboratory have identified the overtone of the CD stretch and a persistent Coriolis perturbation of *all* states with CC stretch excitation. UV-UV double resonance studies of the acetylene E^1B state continue. In DCCD, they see levels assigned in the one-photon absorption spectrum to the so-called F state. The standard interpretation of the electronic spectrum based on a comparison between spectra of HCCH and DCCD needs to be completely re-evaluated. A rotational analysis of HCCH strongly suggests that the equilibrium geometry of the E state is near *trans*-bent non-planar, which is consistent with Wilkinson's vibrational analysis and in agreement with the predictions of the Walsh diagrams for this electronic configuration. A complete rotational and vibrational re-analysis of all electronic states at this energy is currently in progress.

Professor Keith A. Nelson of the Department of Chemistry and his colleagues conducted two sets of activities in the Spectroscopy Laboratory this year. First, they recorded Raman spectra of several nonlinear optical glasses in connection with a joint project involving Corning Glass Works. The spectra provided information about the dynamics and extent of ionic motions which occur in response to femtosecond pulse irradiation. This is important in ultrafast device applications, where the electronic and nuclear responses to pulsed irradiation both contribute to the device's response to an optical or electrical signal.

In a new project, we have begun to construct a femtosecond spectroscopy system in the Spectroscopy Laboratory. A synchronously pumped femtosecond dye laser is now in operation, and the assembly of a synchronously pumped amplifier is in progress. This system will be used for ultrafast time-resolved spectroscopy of chemical reactions and molecular dynamics in organic liquids and in biological materials.

Professor Stephen J. Lippard and Dr. Axel Masschelein have constructed the first stopped flow resonance Raman spectroscopic facility. This instrumentation is being used to study transients in the reaction of oxygen with dinuclear iron centers in model complexes and proteins that oxidize methane to methanol. Intermediates in this chemistry, such as organic peroxides, are also being examined as reactants. The methodology will also be used to examine the reaction dynamics and intermediates in several organometallic projects, including the reductive coupling of carbon monoxide and vitamin B-12 model chemistry.

During the past year Professor Mark S. Wrighton of the Department of Chemistry and his collaborators have been involved in studies of the dynamics of excited state electron transfer involving molecules in solution, molecules anchored to surfaces, and processes between molecules in solution and molecules anchored to a surface. The experimental studies require use of transient Raman and absorption spectroscopy and measurements of luminescence lifetimes. The overall aim of the studies is to understand the factors controlling rate of forward and reverse electron transfer in assemblies of molecules constructed to duplicate the early events in natural photosynthesis. One project has established the difference in driving force dependence for excited state electron transfer vs. energy transfer when photoexcited metal complexes are quenched by ferrocene derivatives: a large driving force, about 1eV, is needed to make the efficiency for the electron transfer process equal to the energy transfer process, presumably due to the larger solvent reorganization energy associated with the electron transfer process. In a second project, conducted with Postdoctoral Research Associate Dr. Charles Christ, studies have established that electrode-confined molecular assemblies can be used as the elements needed to absorb light and separate charge to sustain the photooxidation of so-called sacrificial reagents such as organic amines.

Professor Steven R. Tannenbaum and Drs. Billy W. Day and Paul L. Skipper of the Department of Chemistry/Division of Toxicology have continued their studies of the fluorescence of protein and DNA adducts of chemical carcinogens in collaboration with Drs. Ramachandra R. Dasari, Mark M. Doxtader, Richard P. Rava, and Kuldip Singh of the Harrison Spectroscopy Laboratory. Through a combination of synthetic chemistry, mass spectrometry, room temperature fluorescence, and cryogenic laser-induced fluorescence line narrowing spectroscopy, quantitation and qualitative structural analysis of the adducts formed between the active, electrophilic metabolites of environmental xenobiotics and biological macromolecules are being performed. The structure of the human serum albumin-benzo [a] pyrene diol epoxide adduct has been characterized by use of the above techniques. Efforts toward the use of the fluorescence line narrowing techniques as a means to quantitate adducts in humans at the attomole to femtomole range are continuing.

Laser pulsed probing of mechanical properties of homogeneous and heterogeneous solids is being used by Professor Ali S. Argon of the Department of Mechanical Engineering in a variety of separate applications. Two of the most important applications involve: a) measurement of the tensile strength of single phase solids and of planar interfaces characteristic of those encountered in composite materials between a fiber and its coating; and b) measurement of the elastic properties of micro-porous ceramics. In the first case the tensile strength of a solid or an internal interface is measured by a short wave length, high amplitude tension pulse resulting from the reflection of a compression pulse from a free surface. The conditions of the resulting spallation fractures are then interpreted with the aid of a computer program to determine the intrinsic cohesive strength of a solid or the tensile adhesive strength of a planar interface. In the latter case, the effect of certain key impurities on the degradation of the strength of such interfaces is of interest. In the second case, related to reaction bonded silicon nitride with 75% density and a series of topologically interconnected pores of ca. 50-100 nm pore channels, the effect of such channels on the elastic properties of the solid are being studied by a pulse-echo method of sound velocity measurement in thin samples. These techniques that lend themselves well to such measurements of fundamental properties have proved to be extremely useful in probing the internal constitution of some advanced engineering solids.

During the past year Prof. Alexander Rich and his collaborators have been using ultraviolet lasers to crosslink proteins to left-handed Z-DNA. Dr. Alan Herbert has isolated partially purified proteins and added Z-DNA in solution. Upon exposure to a high intensity ultraviolet laser, the protein is crosslinked to the DNA and this makes it possible to purify the protein and identify it. Drs. Stefan Wölfl and Burghardt Wittig have used permeabilized mammalian cell nuclei with monoclonal antibodies against Z-DNA diffused into them. Nuclei were exposed to the high intensity ultraviolet laser which crosslinked the antibody to the left-handed Z-DNA in the nucleus. Using restriction enzymes, it is possible to isolate the DNA fragments containing the antibody and in this way demonstrate which segments of individual genes flip into the left-handed Z conformation when the gene is actively being transcribed.

Professor Mounji Bawendi from the Chemistry Department initiated a new research project studying the fluorescence properties of semiconductor nanocrystallites as a probe of their surface electronic structure. The SPEX Fluorolog is being used for cw characterization of samples of CdSe and CdS nanocrystallites where the growth process has been purposely altered with a view to changing the nature of the surface electronic trap states. A new sample mount for temperature studies from room to liquid helium temperature has been built and fits into the sample compartment of the Fluorolog. Using the fluorescence results as a guide a growth process which minimizes surface carrier recombination and which gives nanocrystallites sizes from 15 to 85 Å has been perfected.

Professor Toyochi Tanaka, Drs. Sridhar Gorti, and Toyooki Matsuura all of the Department of Physics, have begun to work on the cornea as a part of the project of studying the molecular mechanism of tissue-laser interaction. The cornea was chosen as a model tissue because of its rather simple and homogeneous structure. The fluctuations of light scattered from the cornea was observed using the technique of microscope dynamic laser light scattering spectroscopy (MLLSS). The scattering was from the collective diffusion modes of the collagen-glycosaminoglycan gel. The time correlation function of the scattered light was determined as a function of position within the cornea for two scattering vectors, parallel and perpendicular to the corneal surface. The correlation functions were only weakly dependent on the position and on the direction of the scattering angle. They were fitted well by two exponentials indicating two diffusive modes within the gel network. Critical divergence and critical slowing-down were found in the cornea when a lateral tension was applied on the cornea: Scattered light intensity and the correlation time increased and appeared to diverge as the tension approached a critical value. This constitutes a strong evidence that the corneal opacity that appears at the acute glaucoma or when the eye ball is exposed to a pressure during an operation is due to the reversible phase transition of the corneal gel. The similar critical behavior was observed when the temperature was increased. The temperature dependence indicates that the hydrophobic interaction plays an essential role in the phase equilibrium and dynamic properties of the cornea. The studies further demonstrated the usefulness of the technique of MLLSS in diagnosis of the cornea, the lens and the vitreous body.

This particular study of the cornea is shared by the other NIH supported project entitled Clinical laser light scattering spectroscopy of the lens. The purpose of the two projects are completely different, but the knowledge obtained in this study is vital for both projects.

Professor David Pritchard, Dr. Alex Martin, Dr. Wolfgang Ketterle and their colleagues have demonstrated a novel method for slowing atoms. A high flux of sodium atoms with velocities smaller than 50m/s has been obtained by passing a thermal sodium beam through a cavity with diffuse laser light. This new scheme demonstrated for the first time the use of isotropic, unpolarized light to slow atoms, using angle-tuning of the frequency to compensate for the changing Doppler shift. This technique greatly facilitates the production of slow atoms which will be used in atom traps, precision spectroscopy, atom interferometry and collisional studies.

The spectroscopy of the diamagnetic Rydberg atom carried out under the direction of Prof. Daniel Kleppner is playing a central role in quantum chaos and the physics of non-separable systems. During the past year a group at Ecole Normale Supérieure in Paris developed an algorithm for computing the spectrum: the agreement between calculation and experiment is extraordinary. Another group, at JILA, has developed a qualitative explanation of the spectra which relates the apparently disorderly spectrum to a simple underlying structure. Work has begun on a new apparatus which should allow the spectroscopic studies to be vastly extended.

Professor Feld, Drs. Dasari, and Michael Otteson all of the Spectroscopy Laboratory, have successfully measured the laser-induced anisotropy in the gamma ray decay distribution of short-lived ($1\mu\text{s}$) $^{85\text{m}}\text{Rb}$ atoms. Recent experiments have succeeded in obtaining sub-Doppler resolution anisotropy signals for the first time, which allows us to measure the nuclear quadrupole moment of $^{85\text{m}}\text{Rb}$.

Professor Feld and Dr. Dasari and their colleagues are continuing experiments to study the interaction of single atoms in an open optical resonator. Past experimental results have included enhancement and suppression of spontaneous emission, as well as observation of radiative level shifts of a visible atomic resonance line. Additional experiments have revealed low lying atom-cavity dressed states, showing evidence for energy exchange between atom and resonator mode, a system which can be viewed as two fundamental damped coupled quantum oscillators. Such results have led to measurement of the atom-cavity coupling constant (sometimes referred to as the vacuum Rabi frequency). Future experiments will include further study of atom-cavity coupling effects as well as onset of stimulated emission effects. This work is part of a long-term program to study superradiance and other coherent radiative processes in an optical resonator.

Professor Ali Javan and Dr. Michael Otteson of the Spectroscopy Laboratory have completed experiments using a diode laser to record the spectrum of the ν_3 vibrational band of Sulfuryl Fluoride. The high resolution spectra obtained in these experiments has been used in a least squares fit computer program to determine the band center of this vibrational

transition, and the excited state molecular constants. These results will be used to research the possibility of pumping the SO_2F_2 molecule with a CO_2 laser to develop a laser at approximately 18 microns. In parallel with this work, experiments are underway to develop high speed metal-oxide-superconductor (MOS) junctions to measure infrared and optical frequencies. This part of the research is aimed at making it possible to count the cycles of optical radiation..

Professor Feld and Dr. Rava of the Spectroscopy Laboratory are engaged in biomedical research using laser induced fluorescence to diagnose disease in human tissue. Fluorescence contour mapping is being utilized to understand the emission of tissue in terms of individual fluorophores in the tissue, and to choose the optimal excitation wavelengths for diagnosing disease. Fluorescence spectra from individual tissue components using a fluorescence microscope have been measured, and permit an understanding of the emission on a morphological level. Modeling the tissue using this information has allowed for diagnostic algorithms which have a sensitivity of over 90% for detecting disease in artery wall, colon and urinary bladder. In collaboration with colleagues at the Cleveland Clinic Foundation, laser-induced fluorescence and the diagnostic algorithms are being utilized in a clinical setting to detect disease in artery and colon.

Dr. Rava and Prof. Feld are also engaged in biomedical research using vibrational spectroscopy to diagnose disease in human tissue. Both infrared absorption and near infrared Raman scattering are being utilized to determine the biochemical constituents in different tissues which are primary causes or results of different pathologic processes. In addition to increased diagnostic capability compared to laser induced fluorescence, vibrational spectroscopy allows direct histochemical information to be obtained in situ, without tissue removal.

Professor Feld, Drs. Dasari, Rava and Manoharan, all of the Spectroscopy Laboratory have initiated basic research on individual constituents of human artery using FT-IR and FT-Raman techniques. These tissue components include collagen, elastin, cholesterol, cholesterol esters, phospholipids, triglycerides, glycosaminoglycans and calcium hydroxy apatite. The spectral data will be used to interpret the spectra of different pathologic human arterial tissues.

Professor Feld, Dr. Irving Itzkan, Dr. G. Sargent Janes and their colleagues are continuing experiments to understand the mechanisms governing laser ablation of tissue for microsurgery and various percutaneous applications. In particular, schemes for the effective removal of hard tissue, such as calcified atherosclerotic plaque, are being examined. Experiments such as temporal measurements of the hard tissue ablation process and fluorescence measurements during ablation are being utilized to understand the mechanism of ablation. A gasdynamic analysis of the process is also being pursued to help guide the experiments. In parallel with this work and in collaboration with colleagues at the Cleveland Clinic Foundation, a clinical system is being developed for diagnosing and treating atherosclerosis using laser light delivered percutaneously through optical fibers.

Professor Feld, Dr. Firooz Partovi, and Dr. Irving Itzkan of the Spectroscopy Laboratory have generalized the theory of thermal laser ablation to treat very high laser intensities. This has involved gas-dynamic calculations in one dimension. It needs to be further generalized to transient time regimes before it can be fully applied to pulsed ablation.

Professor Feld, and Dr. Dasari, of the Spectroscopy Laboratory, studied laser-induced fluorescence of tissue in the time domain with picosecond lasers. Fluorescence decay behavior of normal and plaque artery has been studied to establish tissue diagnosis in time domain. The 320nm excitation - 380nm emission combination results show that fluorescence decay can be used to identify tissue type.

MICHAEL S. FELD

Laboratory for Nuclear Science

The Laboratory for Nuclear Science (LNS) provides support for research by faculty and research staff members primarily in the fields of basic nuclear and elementary particle physics, including the activities of the Center for Theoretical Physics and the Bates Linear Accelerator Center in Middleton, Mass. In addition, it provides a computing facility, shops, and an electronics design and development facility for its programs. The primary experimental programs are in three areas. The largest local effort is in intermediate energy nuclear physics, at the Bates Linear Accelerator Center in Middleton, Massachusetts. There is a users group in relativistic heavy ion physics with activities at Brookhaven National Laboratory (BNL). The Laboratory also has a users' group at the Los Alamos Meson Physics Facility (LAMPF) and at the Paul Scherrer Institute (PSI) in Switzerland and at Continuous Electron Beam Accelerator Facility (CEBAF). In high energy physics, there are major projects in the US at Fermi National Accelerator (FNAL) in Batavia, Illinois; and the Stanford Linear Accelerator Center (SLAC) in Palo Alto, California; and abroad at the European Center for Nuclear Research (CERN) in Geneva, Switzerland; and at the Gran Sasso Laboratory in Italy.

EXPERIMENTAL HIGH ENERGY PHYSICS

Electromagnetic Interactions Group (EMI)

Following the six year construction and installation program of the L3 experiment at the LEP accelerator (Large Electron Positron Collider) at the European Organization for Particle Physics Research (CERN) in Geneva, Switzerland, the Electromagnetic Interaction Group (EMI) led by Professor Samuel C. C. Ting has been taking data since the machine first became operational in the summer of 1989. To date 33 scientific papers from L3 have been published including the first publication from LEP. L3 is the largest of the four LEP detectors and is distinct from the other detectors in its design and physics objectives. L3 is an ultra precise detector built with state of the art technology to study photons, muons and electrons with unprecedented accuracy. Collaborating with the MIT/LNS/EMI group on L3 is an international consortium of 479 physicists from 44 institutes and 13 different countries. It represents the first large scale high energy physics experiment in which scientists from the United States, the Soviet Union, China, and India, work together with the strong support of their respective governments. As in the past twenty five years, the EMI group continues to bear the leading responsibility for the design, construction, installation, execution, and data analyses of all its experiments.

The LEP machine has been operating at a luminosity of $2 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1}$. To date L3 has collected and analyzed more than 170k Z^0 particles (the carrier of the electroweak force) and with this data sample have been able to carry out many indepth studies, among which are the following:

-We have measured the mass and width of the Z^0 and were the first group to directly measure the branching ratio of the Z^0 into electron and muon pairs. We have found:

The mass of Z:	$M_Z = 91.181 \pm 0.010 \pm 0.02$ (LEP) GeV, and
The total width of Z:	$\Gamma_Z = 2.501 \pm 0.017$ GeV,
The hadron width of Z:	$\Gamma_{\text{had}} = 1.742 \pm 0.019$ GeV.

-In the framework of the Standard Model, our results show that there are only three kinds of neutrinos in the universe (3.05 ± 0.10).

-We have set limits on the mass of the Top quark ($M_t = 193^{+52}_{-69} \pm 16$ GeV).

-In the search for new particles, we have set limits on the mass of the charged Higgs

and neutral Higgs boson ($M_{H^0} > 41.8$ GeV and $M_{H^\pm} > 36.5$ GeV at 95% c.l.) as well as Supersymmetric particles: scalar muons, scalar electrons, winos, and scalar leptoquarks as well as New Charged and Neutral leptons: excited electrons, muons, taus and neutrinos. (In all case, a lower limit > 41 GeV at 95% c.l. has been obtained).

-We have determined that electrons, muons and taus all have a radius smaller than 10^{-17} inches.

-In the physics of heavy quarks, $B^0 - \bar{B}^0$ mixing and b quark asymmetries have been studied. L3 has uniquely observed the reaction $Z^0 \rightarrow B \bar{B}$ in which B changes to \bar{B} with a probability of X_B . The signature of this phenomena is the observation of two same sign opposite side high- p_\perp leptons. Our measurement is 80 away from $X_B = 0$. We have obtained

$$X_B = 0.178 \begin{matrix} +0.049 \\ -0.040 \end{matrix}$$

-The strong coupling constant α_s has been measured ($\alpha_s = 0.115 \pm 0.009$) to second order QCD from energy-energy correlations. We have determined that all quarks have a radius smaller than 10^{-17} inches.

-We have made the most precise measurements to date on the neutral current vector g_V and axial vector g_A coupling constants and we have found:

$$\bar{g}_V = -0.046 \begin{matrix} +0.015 \\ -0.012 \end{matrix}$$

and

$$\bar{g}_A = -0.500 \pm 0.003.$$

L3 plans to continue the search for new particles and physics phenomena on the frontier of physics research. LEP is planning to double its luminosity in 1991/1992 yielding 10^6 Z^0 's for L3 to analyze in 1991. The luminosity will continue to increase and by 1995 LEP will cross the $W^+ W^-$ production threshold (LEP200). It is at these highest LEP luminosities that the unique advantages of the L3 detector in its design, precision performance and physics potential will be fulfilled.

Proton-Antiproton Physics

Two LNS groups with common physics interest have joined in a common effort in the CDF Collaboration at Fermi National Laboratory. This new group was recently formed to study proton-antiproton collisions at $\sqrt{s} = 2$ TeV. Part of this new group is coming from the UA1 experiment at CERN, the other part comes from the SLD experiment at SLAC.

The UA1 group had been studying proton-antiproton collisions at the CERN Sp \bar{p} S Collider in Geneva, Switzerland. The center of mass energy range extended from 200 GeV to 900 GeV. Most of the data were taken at 630 GeV.

They participated in the discovery of the W and Z particles, the intermediate vector bosons of the electro-weak interaction and studied in detail the properties of these new particles. Some of the many other important physics results include:

- light neutrino species counting (< 5.9 , 90% C.L.),
- search for new sequential heavy lepton $m_L > 41$ GeV/c² (90% C.L.),
- search for new fundamental particles such as new heavy quarks (top-quark: $m_{top} > 60$ GeV/c² (95% C.L.), b' quark (fourth generation charge 1/3 quark): $m_{b'} > 43$ GeV/c² (95% C.L.) etc...)

- study of the production and decay properties of heavy quarks (charm and beauty) led to the observation of weak mixing between the $B^0_{s,d}$ and $\bar{B}^0_{s,d}$ meson states. Such mixing had until then been observed only in the classic K^0 - \bar{K}^0 system. The total b-quark production cross section was measured and a search for rare B meson decays was completed.

While the analysis of some of the UA1 data is continuing, this group is planning to pursue its investigations of proton-antiproton collisions at much higher energies: $\sqrt{s} > 1.8$ TeV, at the Fermilab Collider. The next data taking period should start in the spring of 1992 and last about two years. The physics priority is the search for the top quark. If the Standard Model is valid, the top quark mass should be lower than about 200 GeV/c². Most of the range between the present lower limit and 200 GeV/c² should be covered in the next few years.

This group has developed expertise in a new type of calorimeter using alternating layers of uranium and a warm organic liquid (tetra-methylpentane known as TMP). MIT has built the most intricate part of such a calorimeter, a position detector mounted behind 3.4 radiation lengths of uranium/TMP, providing a spatial resolution of about 1mm.

This group is also involved in the development of alternative computer technologies to provide the vast amount of CPU power needed to analyze data. In particular, "farms" of 3081E processors attached to small IBM mainframes have been developed in collaboration with SLAC and CERN. One of these powerful emulator farms with seven 3081E emulators is now installed at MIT.

The Accelerator Physics Collaboration

The Accelerator Physics Collaboration (APC) group is conducting experimental research at Fermi National Accelerator Laboratory (FNAL) in Illinois, the Gran Sasso (GSL) at L'Aquila, Italy, and Brookhaven National Laboratory.

The group has recently taken data at FNAL in the world's highest energy neutrino beam, utilizing a holographic bubble chamber. This experiment is investigating a new domain in neutrino physics. This experiment is now complete and final papers are in the preparation stage. The group is now involved in a new Fermilab experiment (E-782), which again uses the holographic bubble chamber, to study μ mesons interactions with nucleons. This experiment is now taking in a region inaccessible to other techniques. The data taking stage of this experiment is now complete.

The experiment in GSL, which is the world's largest underground laboratory, will study particle physics and astrophysics problems. The particle physics problems are related to the possibility of a new type of particle being emitted from Cygnus X-3. These studies could confirm emission of such particles and provide information on the mechanisms involved and the properties of the source. This experiment can also search for neutrino oscillations. The group will also study the production of solar neutrinos and will measure the yearly rate of collapsing stars in the universe. Another objective is the search for point sources in the universe emitting high energy neutrinos.

The group has now joined a Brookhaven National Laboratory experiment to study the creation of strangelets which are particles that contain more than three quarks with a large number of the quarks having strange flavor.

The Counter Spark Chamber Group

The Counter Spark Chamber Group is continuing the development of the Stanford Large Detector (SLD) at the Stanford Linear Accelerator. The CSC Group constructed the Warm Iron Calorimeter and Muon Detector for SLD. This subsystem was the first completed for the detector and now the rest of the detector is completed and installed in the beam. Currently we are engaged in an engineering run to shake down the detector and the accelerator. The

accelerator group is now preparing a polarized electron beam preparatory to an SLD run early in 1992. The CSC Group is looking forward to performing an incisive test of the Standard Model, via the measurement of the difference in the e^+e^- production of fermions with left and right circularly polarized beams. The group continues its involvement in the deep inelastic scattering of muons of nuclei at Fermilab in an effort to understand the formation process of hadrons.

The CSC Group has undertaken two new initiatives directed toward the longer term future, they are:

- 1) Development of a detector for the relativistic heavy ion collider (RHIC) which will be built at BNL by the middle 90's. A proposal has been submitted in collaboration with the heavy ion group and is awaiting action by BNL.
- 2) Participation in the preparation of a proposal for a major detector for the Superconducting Super Collider. The group is active and will take a major role in the design and development of the so called "second detector" for the SSC. This detector is planned to have superior lepton detection capability. In this connection, the group has undertaken muon detector research and development
- 3) The group is participating in the CDF proton-antiproton collider experiment at FNAL in collaboration with the UA1 group (see sec "The Proton-Antiproton Physics")

Lepton Quark Studies (LQS)

The LQS group is continuing its collaboration on the SLD experiment with the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is presently participating in the commissioning of the experiment and is also involved in the commissioning of the polarized electron beam. With this polarized electron beam, SLD will be able to study production of Z-bosons with left- and right-handed polarized electrons, allowing tests of the present gauge theory with unprecedented precision. Because of schedule delays and difficulty in attaining SLC design goals, the group is embarking on two other new research projects centered at SLAC, to augment their physics programs:

- 1) A collaboration has been formed between US and Chinese groups to exploit high statistics studies of electron-positron interactions in the 3 to 5 GeV energy region with the Beijing Spectrometer situated at the Beijing Electron Positron Collider (BEPC) at the Institute for High Energy Physics (IHEP) in Beijing; a follow-up of very fruitful experiments carried out at SPEAR, SLAC's former storage ring collider facility, during 1982-89.

- 2) An e^+e^- international facility operating in the SPEAR energy region is being pursued. Known as the Tau-Charm Factory, it will have even rates 100 times and 1000 times more than BEPC and SPEAR, respectively, with a high precision spectrometer, allowing for continued studies of charmed mesons, charmonium states and properties of the tau lepton.

EXPERIMENTAL NUCLEAR PHYSICS

Relativistic Heavy-Ion Physics (HI)

The Heavy-ion Group is a large part of the E802/E859 collaboration, which has constructed a multi-particle spectrometer that can measure the reaction products produced in collisions induced by the 235 GeV oxygen and 412 GeV silicon beams that have recently become available at the Brookhaven National Laboratory Tandem/AGS accelerator facility (unique in the U.S.). Using these beams, collisions with heavy target nuclei, from aluminum to gold, offer far higher matter/energy densities than heretofore studied, approximating conditions that may have occurred during the initial expansion of the universe. In each central collision hundreds of particles are produced. analysis of the produced particle multiplicity and transverse energy flow, as a function of target nuclear size, indicates that the projectiles, even at this very high energy, are indeed stopped during central collisions with the largest nuclei, producing energy densities several-fold higher than in normal nuclear matter. Analysis of the spectrometer data has yielded the provocative result that

the production of positive strange mesons (K^+) relative to normal π^+ mesons is threefold enhanced compared to proton induced reactions. We are just now analyzing data obtained from the Spring 1991 run that utilizes a newly installed "smart" trigger. By performing particle identification within 10 μ sec this allows on-line event selection, thereby increasing our data sample for K^+ by over a factor of 10. The tracking detector system is being upgraded in order to exploit the much heavier and energetic (2700 GeV) gold beams that will become available when the AGS booster synchrotron is commissioned in 1992, allowing one to reach even higher matter/energy densities. Furthermore, the MIT group has submitted a Letter of Intent, with Prof. Wit Busza as spokesman, for the MARS detector for the Relativistic Heavy-Ion Collider (RHIC), which is now under construction at Brookhaven. This machine will have almost 40 TeV center-of-mass energy for gold-gold collisions beginning in 1998.

Intermediate Energy Nuclear Physics

About 30 MIT graduate students were associated with the intermediate energy research program during the past year.

Many of the faculty in intermediate energy nuclear physics have recently been involved in an experiment at Bates to provide a complete characterization of the electromagnetic structure of the deuteron, the most elementary nucleus. This difficult experiment involved the necessity to perform a double scattering measurement to determine the spin orientation of the struck deuteron. Final results are now available and indicate that "traditional" nuclear models which do not include quark-gluon degrees of freedom are sufficient to describe the data, even at this relatively large momentum transfer. A complementary measurement of the deuteron magnetization confirms the dominant role of meson currents at large momentum transfer.

Work on characterizing the $(e, e'p)$ response function continues. Evidence is accumulating that multinucleon absorption of the virtual photon is an important process. Special attention is being paid to studies on carbon and light nuclei. Associated results on deuteron knockout suggest an interesting correlation structure.

The parity experiment which is described in some detail below in the section on Bates research involved major contributions from MIT faculty and research staff. The MIT group is also involved in a new parity experiment at Bates aiming to explore the proton's quark structure.

Several initiatives concerned with spin measurements are being pursued actively. For example, high-density polarized helium gas targets are being developed. Several interesting applications are envisioned, based upon the property that polarized ^3He offers the chance to study neutron properties. The first experiments using such targets at Bates have recently been completed, as has the first spin transfer experiment (aiming at the neutron's charge distribution).

Complementary to the Bates experiments are investigations by the MIT groups at other accelerator facilities. The largest such program at present involves studies of the pion-nucleus interaction at Los Alamos (LAMPF) and at Zurich (PSI). The MIT group is also a leader in the proposal to measure nucleon structure functions using polarized electrons at DESY. These experiments will also make use of the polarized target technology being pioneered at MIT. A new effort is starting to construct detectors for the new Continuous Electron Beam Accelerator Facility in Virginia. We expect this effort to grow significantly in the next few years.

Design of a solar neutrino detector, called BOREX, utilizing nuclear neutrino interactions is progressing in collaboration with groups at AT&T Bell Laboratories, Milan University (Italy), Argonne National Laboratory, and others.

Bates Linear Accelerator Center

a. Few-body Systems

The electromagnetic structure of the nucleon and of the simplest nuclei, those amenable to microscopic theoretical analysis based upon the best available models of the nuclear force, continue to be a major focus of the Bates research program. A double-scattering experiment examining the polarization observables in electron scattering from deuterium has provided the first full characterization of the ground state charge structure of this most elementary nucleus. The experiment has reinforced the appropriateness of hadronic descriptions at length scales well below 10^{-13} cm. Another measurement has provided the magnetic structure of deuterium to very small distance scales, showing the importance of mesons. Nucleon structure is being explored in several ways. The neutron charge distribution will be measured in two complementary ways. One involves scattering polarized electrons from polarized ^3He nuclei. The second involves a double scattering experiment measuring the polarization of neutrons knocked out from deuterium. Another program will examine the deformation of protons. All of these programs require major technical developments and involve a novel use of polarization observables. The polarized target development provides the basis for our leading role in a major experiment planned at DESY (Hamburg) which will measure proton and neutron quark distributions.

b. Electron-proton Coincidence Experiments

Electron-proton coincidence experiments continue to be an important program at Bates. An extensive program using carbon as a target has yielded a series of important results. A measurement made to very large momentum transfer, 1 GeV/c, is consistent with the proton maintaining its integrity in the nuclear medium. Furthermore, a surprisingly large yield of deuterons has been found, suggesting further studies of the correlation structure of nuclei. A new set of precision measurements on the deuteron has begun, using the first of a set of four out-of-plane spectrometer under construction.

c. Parity

Parity non-conservation, a violation of reflection symmetry in nature, arises from the weak force. The very small difference (less than one part per million) in scattering electrons in two different polarization states from a spherical nucleus was measured at Bates. The difference was found to be consistent with that expected in the Standard Model of elementary interactions. The next such experiment will measure parity violation in electron-proton scattering and is now in the testing phase. The result will provide the first experimental information on the strange quark contribution to nucleon magnetism.

d. Pion Physics

Most of the current work outside the Bates Laboratory involves pion induced reactions at Los Alamos and PSI. An extensive program of charge exchange measurements is continuing at LAMPF. The MIT group helped build a new large acceptance detector for studying pion absorption at PSI. The first data obtained with this detector are in the final stage of analysis.

e. South Hall Ring

The Bates research program has done much to frame the questions and to establish the experimental basis for the future electronuclear studies needed to advance nuclear physics along new directions. The new capabilities needed have been identified: continuous (CW) beams and full utilization of polarization observables. The South Hall Ring (SHR) project at the Bates Laboratory is an experimental initiative which will provide these capabilities throughout the important energy range accessible to the existing accelerator (i.e., up to 1 GeV). The South Hall Ring will be completed 1992. It will be an integral part of the South Experimental Hall using existing beam lines for experiments in the internal target mode and in the extracted beam mode.

In the internal target mode, the electrons are circulated thousands of times through a windowless gas target introduced into the ring. The major benefit of this configuration is

that it permits (and requires) the use of exceedingly thin targets, i.e., targets so thin that an insufficient number of interesting collisions would take place if each electron passed through the target only once. There are several advantages to this approach. One is that heavily ionizing reaction products are able to leave the target and reach the detector. This possibility is central to a number of planned experiments, for example, those aimed at a basic understanding of nuclear fission or of the propagation of pions in the nuclear interior. Perhaps the most exciting prospect, however, is that associated with polarization. Advances in laser technology and surface science now make it feasible to produce gases of polarized nuclei of sufficient thickness for internal target use. Such internal target experiments, representing a significant departure from the traditional experimental configuration in electronuclear physics, will require innovative developments advancing both physics and technology. A major new detector called BLAST (Bates Large Acceptance Spectrometer Toroid) is being developed in collaboration with scientists from eight other institutions. This large acceptance detector is matched to the luminosity and polarized target requirements of the SHR internal target facility.

In the extracted beam mode, the SHR will be used as a pulse stretcher. The basic idea is that the SHR will capture each accelerator beam pulse and then "leak" the electrons to the experiment uniformly between pulses. The technical challenge lies in performing the filling and emptying procedures efficiently, rapidly, and yet smoothly. We anticipate a broad program, for example, in exploring nuclear collective motion, in mapping the nuclear spectral function, and in measuring the nuclear pion distribution near threshold

E. J. Moniz, Director

THE CENTER FOR THEORETICAL PHYSICS

Nuclear Theory

The goal of theoretical nuclear physics research at MIT is to understand the structure and interactions of the hadrons, atomic nuclei, and hadronic matter of which our universe is composed. Major research areas include hadronic structure and interactions, QCD and its effects in nuclei, relativistic heavy ion physics, nuclear many-body theory, chaos in nuclei, and electromagnetic, weak, and hadronic probes of nuclei. This research program combines new initiatives in emerging fields with active ongoing efforts in areas in which MIT has traditionally played a leading role. Theoretical research continues to benefit from strong interactions with experimentalists in electromagnetic and relativistic heavy ion physics and contributes significantly to these experimental programs.

Hadronic structure, QCD, and the role of QCD effects in nuclei are primary topics of research, both because of their fundamental significance and the unique resources at the interface between nuclear and particle physics in the Center for Theoretical Physics. A major recent thrust has been the study of confinement, giving rise to a new understanding of confinement in terms of the propagation of quarks in a fluctuating color field. A variety of analytic approaches to QCD are being explored, ranging from classical solutions to mean field and variational calculations. Particular emphasis is being given to systems containing one heavy quark, for which essential simplifications occur. Lattice gauge theory, which provides a unique tool to solve, rather than model or approximate QCD, has recently been exploited to calculate wave functions and quark correlation functions for the pion, rho, and proton which have been compared in detail with bag and Skyrme model results. A major success is the calculation of charge radii for the pion and nucleon in agreement with experiment. Pioneering studies of the use of deep-inelastic lepton scattering as a probe of nucleon and nuclear structure have continued, with particular emphasis on spin-dependent structure functions.

Theoretical investigations in relativistic heavy ion physics at MIT lie at the heart of fundamental exploitations of new regimes of hadronic matter under way at Brookhaven and CERN and anticipated for RHIC. Pioneering studies of J/ψ suppression as a possible

signature of a quark-gluon plasma have continued, with emphasis on dynamic plasma screening and final state interactions. The propagation of high-energy quarks and gluons in a plasma has been studied to explore the utility of using hard processes to probe quark-gluon plasma formation. A flux tube model of heavy ion collisions developed previously was extended to study dilepton production. The novel idea of using heavy ion collisions to produce Higgs bosons coherently has also been explored.

Nuclear many-body theory provides the foundation for many aspects of nuclear theory, and has thus been an area of continuing interest. A major focus of recent research has been understanding the role of chaos in nuclear physics and the relation between classical and quantum chaos. A coherent state representation has been shown to provide a useful bridge between quantum eigenstates and periodic classical solutions. Efforts have continued to understand the nature of periodic solutions in multi-dimensional classical systems and their implications for quantum chaos and to calculate periodic solutions for physical processes. Path integral techniques, which have previously been used by this group for a wide variety of nuclear many-body problems, have been applied to the nuclear response function and nuclear level densities. The distribution of momentum in deformed nuclei has been studied in models, in mean field theory, and in $(e, e'p)$ experiments. Several new approaches are being applied to nuclear many-body theory, including scattering theory and perturbation theory in a time-dependent basis, application of the doorway state method to ground state properties, and the use of light cone techniques.

Electromagnetic probes of nuclei have been a continuing focus of theoretical interest, both because of the unique precision of electromagnetic probes and important new opportunities to exploit coincidence experiments and polarization observables arising from the Bates program and South Hall ring project. Measurements of parity violation in nuclei provide a unique window to study fundamental symmetries and explore the parity non-conserving component of the nucleon-nucleon interaction. Important developments include the discovery of enhanced, and thus potentially observable, anapole moments (which are odd under parity but even under time reversal) in specific nuclei, and calculations of the role of isospin mixing and electroweak corrections in nuclear parity violation measurements. Research to exploit the unique capabilities of polarization and coincidence measurements has continued, and the role of nuclear correlations in the nuclear response function is being investigated.

Research in hadronic interactions addresses both the nature of the hadron-hadron interaction, which is essential for understanding the foundation of low-energy nuclear physics, and the use of hadrons and nuclei as probes of nuclear structure. Two-baryon interactions have been studied in the Skyrme model and using a hybrid bag model with external meson fields, with the goal of exploring coupled channel effects and possible exotic resonances. The role of $SU(3)$ symmetry in baryon-baryon scattering has been explored and shown to have strong implications for the existence of Σ hypernuclei. One of the underpinnings of the relativistic phenomenology for nucleon-nucleus scattering had been called into question by the demonstration that the second-order non-relativistic optical-potential can explain medium energy polarization observables, and statistical multi-step reaction theory has been applied to deep-inelastic heavy ion scattering.

Much of the vitality of the Center for Theoretical Physics arises from broad interests in general problems in theoretical physics. Thus, the nuclear theory group has also addressed such topics as topological structures, anomalies, and renormalization in field theory, quantum gravity, the electron gas, and solitons.

Particle Theory

Research in particle theory at MIT seeks to extend and unify our understanding of the fundamental constituents of matter and the theory which governs them. During this past year, significant advances have been made in the areas of particle phenomenology,

cosmology, and the theory of fields and strings, as well as in the more general areas of quantum mechanics and mathematical physics.

Spin dependent structure functions, which specify the distribution of quarks and gluons in a hadron of a specific spin orientation, are expected to become accessible experimentally and are therefore of particular importance in particle phenomenology. In the context of the parton model, it has now been understood how to completely specify the full set of independent information about particle structure that can be obtained from measurements in which spins are polarized transverse to the direction of the incident particle. This understanding is crucial in planning future experiments. There has also been progress in resolving an old conflict between two apparently different ways of describing elastic form factors in relativistic systems: a fundamental description in terms of underlying quark degrees of freedom and effective theory formulated in terms of low-lying excited hadronic states.

In collaboration with members of the nuclear group, a new model has been developed for the description of hadron structure. This model is motivated by the understanding gained from lattice gauge calculations about the dominant role that should be played by the non-perturbative enforcement of the color version of Gauss's law.

This year, investigations at the interface of quantum field theory and cosmology have focussed on the problem of the generation of density perturbations in the early universe. Progress was made in delineating the classes of theories in which quantum creation of topological defects during the inflationary phase of the big bang could contribute to the formation of the observed large scale structure in the universe. Also, study of a new model of extended inflation has shown that density fluctuations may be generated on long scales in a way which may be more consistent with present observation.

In quantum field theory, a new way of carrying out the ancient task of regularizing and renormalizing divergent Feynman diagrams has been developed. It has the virtue of simplicity and generality so that the same method can be used for all of the interactions which occur in the standard model. Up to now there has been no such single method which was effective for all interactions.

Understanding the role of topology and quantum symmetry breaking in field theory is an area in which this group has had a long interest and made seminal contributions. Current work has been focussed on field theories in two space dimensional, with particular emphasis on quantum gravity and the theory of the novel vortex-like structures known as anyons which are believed to play an important role in physical two-dimensions condensed matter problems.

In the theory of strings, important advances were made this year in the development of a theory which consistently includes both closed and opened strings. Subtle problems in the theory of open strings alone were shown to be resolved by unification with the theory of closed strings previously developed here.

Finally, some new contributions have been made in the general development of quantum mechanics. A novel class of bound states has been discovered for particles constrained in channels, and general theorems and possible applications are being explored. A new method of constructing quantum amplitudes by an unconventional functional integral has been derived, and work is in progress to develop this approach as a practical new tool in quantum mechanics.

J. Negele, Director

SUMMARY OF SUPPORT

Participants in the various research programs during the past year amounted to approximately 392 people. This includes 40 academic staff members, 92 graduate students, and at least 40 undergraduates from MIT and other institutions. The latter were involved in senior theses, Undergraduate Research Opportunities Programs (UROP), work-study, and similar programs. There were about 105 research staff members with Ph.D.'s including visitors and guests, and 115 employees in supporting categories such as engineers, technicians, machinists, computing and administrative personnel. At least fifteen Ph.D.'s, and two B.S.'s were awarded based on thesis research within LNS.

Support during fiscal year 1991 from the contract with the US Department of Energy (DOE) is expected to total \$27,574,000. This sum breaks down as follows: Operations costs (salaries, wages, materials, services, travel, and overhead) were \$19,964,000, of this \$7,086,000 was for experimental and theoretical high energy physics, \$10,547,000 was for intermediate nuclear energy physics for the support of the Bates Linac Facility and research program both at Bates and elsewhere, and \$933,000 was for nuclear structure theory, solar neutrino, and for heavy ion experiments and \$398,000 for SSC operations. Equipment costs are expected to total \$5,755,000; of this, \$3,792,000 will be for High Energy physics and \$1,694,000 for medium energy and heavy ion physics and \$269,000 for SSC equipment. A total of \$1,855,000 will be expended for accelerator improvement and, general plant construction projects associated with the Bates Linear Accelerator Center. Support for other programs within LNS, including support from other institutions and laboratories for collaborative work undertaken directly by LNS, is expected to total about \$1,827,974.

A. K. Kerman, Director, LNS

George R. Wallace, Jr. Astrophysical Observatory

The George R. Wallace, Jr. Astrophysical Observatory is a teaching and research observatory located in Westford, Massachusetts. Its facilities consist of a 24-inch reflecting telescope, a 16-inch reflecting telescope, several 8- and 14-inch telescopes, a 5 1/2-inch astrograph, and a small building that houses a workshop, darkroom, and observers' quarters. Instruments include the "SNAPSHOT" high speed, dual-CCD photometer, conventional photometers, photographic cameras, and a spectrograph.

Dr. Edward Dunham left the Observatory staff this year to take a position at NASA's Ames Research Center. Dr. Heidi Hammel joined the Observatory staff as a Research Associate and has been promoted to Principal Research Scientist. Her research interests include high-resolution imaging and infrared spectroscopy of planets and satellites in the outer solar system.

Upgrades to Observatory facilities occurred this year included the acquisition of a DEC RISC workstation that will allow the processing of CCD frames at the Observatory, as well as on campus from computers on the network.

In July several high-school students and an astrophysicist from the Soviet Union were given a tour of the Observatory. They were participants in an outreach program entitled "People to People Youth Science Exchange in Astronomy", a program based in Westford, MA. Most of these students live in the astronomy community of Zelenchuk, which is linked with the Soviet government's research station at Bukova.

Last fall 48 students in subject 12S23 (Observing the Stars and Planets) and 23 students in subject 8.287J-12.117J (Observational Techniques of Optical Astronomy) used the Observatory for their laboratory work.

Dr. Dunham, Stephen McDonald, and Professor Elliot completed their search for stars that may be occulted by Pluto or its satellite Charon for the period 1990-95 through astrometric analyses of CCD frames obtained at the Observatory last year. They found 162 potential candidates, of which 32 should be observable occultations from earth. The astrometric precision achieved in this work is 0.2 arc second. These stellar occultations will be the only method for probing Pluto's atmosphere with high spatial resolution for the foreseeable future.

Observing programs included CCD astrometric observations of Pluto stellar occultation candidate stars with the upgraded SNAPSHOT camera by Mr. McDonald and Marcus Babzien. This spring they completed a search for stars that may be occulted by Pluto and its satellite Charon for the years 1996-2000. Mr. McDonald is also supervising a similar program to find stars that will be occulted by Neptune's satellite Triton, which was found to have a tenuous atmosphere by the Voyager 2 spacecraft. Students carrying out the observations—Reba Bandyopadhyay, Christina Ansoorian, James Wooten, and Franz Elizondo—are participating in the Undergraduate research Opportunities Program and are being supported by NSF's Research Experiences for Undergraduates.

JAMES L. ELLIOT

VICE PRESIDENT, EQUAL OPPORTUNITY OFFICER, AND SECRETARY OF THE CORPORATION

The reports that follow this introduction cover the activities for the academic year 1990-91 in the administrative departments for which I am responsible. In addition, a separate report of the Secretary of the Corporation details the activities of M.I.T.'s governing body.

One of the activities not covered in the departmental reports is the program, Building on Differences. Last September I summarized the purpose of this program, open to volunteers from all of the departments in our areas, as follows:

. . . to sharpen our ability to recognize and to welcome, understand, and capitalize on individual and group differences present in our work setting at M.I.T., in order to improve our work productivity, our cooperation and teamwork, and our individual satisfaction and the rewards we derive from work. It is my personal conviction that the time we invest together learning to build on differences will pay off and will prepare us not only to cope with increasing diversity in the work place, but also to increase our contributions and our personal enjoyment from work.

This program was launched in a pilot mode in the spring of 1989, under the name, "Building on Diversity." Twenty-seven staff members volunteered to meet informally in two groups, each for 10 two-hour meetings, during the period from February to August 1989. Dr. Joyce Gibson, a consultant and former head of M.I.T.'s Office of Minority Education, served as facilitator of the two groups and produced a report in the winter of 1989.

Dr. Gibson's recommendations and those of the pilot phase participants led to phases II and III of Building on Differences, the current form of our program: in 1990-91, we held two series of small-group meetings consisting of six and five groups, respectively, each group made up of ten volunteer participants led by a convener. Each group held weekly one-and-one-half-hour meetings for six consecutive weeks. I recruited the following conveners from the staff: Ronald Fleming, Chief, Social Work Services, Medical Department; Jeannette Gerzon, Associate Director, Career Services and Preprofessional Advising; Stephanie Harriston-Diggs, Assistant Dean for Student Affairs; Leo Osgood, Assistant Professor and Head Coach for Basketball, Athletics; Myra Rodrigues, Social Worker, Medical Department; Clarence Williams, Special Assistant to the President and Assistant Equal Opportunity Officer; Maureen Wolfe, Personnel Officer.

Dr. Susan Warshauer, Vice President of Fidelity Investment Company and former manager of staff training in Personnel, worked with the conveners' group and me last summer to design phase II. Sixty-four members volunteered to participate in the fall. Their reactions, discussed in a series of breakfast meetings held for participants after the series, were very positive. With minor modifications suggested by the participants and the conveners, we repeated the series -- in phase III of the program -- attended by 53 new participants in the spring of 1991.

So far, then, about 135 (or 20 percent out of a total of 650) members of the academic, administrative, support, and service staffs in the areas for which I am responsible have taken part in this special program. Nine of them participated in more than one phase. The program is still under active development. This summer, the group of seven conveners is working with me to assess the progress to date and to plan the shape that phase IV should take. Clearly, one of our future activities will be a program for past participants of phases I, II, and III.

Although there is no firm plan yet for the details of the next phase, I wish to make a few general observations for the record at this juncture of what I regard as one of the most promising program initiatives in my 31 years at M.I.T. First, I believe that the issue of exploring, identifying, and building upon personal differences among working colleagues is a cornerstone for effective work in the future. If we mean what we say about recruiting and integrating a diverse work force at M.I.T., then we better face up to the challenge and the difficulty of recognizing, accepting, and learning to value the idiosyncrasies

and the personal differences that individuals bring here through their diverse backgrounds, interests, and points of view. Demographic projections suggest that diversity will increase -- and this means that personal differences of all kinds will be more present, more of a challenge to understand, and -- I would argue -- more of a source of satisfaction for those individuals and those institutions that can manage them effectively. *We should learn to build on differences as assets to be capitalized rather than as obstacles to be eliminated.*

Second, I believe that the Building on Differences program is a means of assuring a continuous and open discourse about how we work together and about the personal values that guide our individual behavior. Whether or not this leads us to change our behavior, or others to change theirs, the open discourse is vital to keeping all of our minds reasonably open to each other's views and to the world outside M.I.T. It is especially vital to do this in a university environment where for students and teachers -- and for other workers at all levels -- the central mission is education and learning. *Continuing to talk about differences is the greatest assurance for continuing to learn.*

Third, I believe that a program about differences has the greatest potential to reach even deeper than our individual values to a layer of unspoken assumptions about what works and about how things work in our institution. It is a means to understand the M.I.T. Culture. Understanding institutional culture is at the heart of both adapting and succeeding in that culture. More importantly, however, understanding is a *prerequisite to any effort to change the culture* in order to adapt to changing times and circumstances, and to the expectations of the world outside our institution.

My fourth observation is more of a realistic assessment of where we are today: The high promise that I hold for our program is matched only by a sense of the difficulty that is involved in working out our goals and realizing our aspirations.

Already in phase III, with 20 percent penetration into the staff population in our areas, we have begun to experience some strains that suggest that building on differences is much more difficult to implement than it is to conceptualize. The strains I see so far take the form of resistance to participation, a skepticism about the program, and, more broadly, about the leadership commitment at M.I.T. to manage people by taking individual differences into account. It is a serious charge that we do not practice what we preach. Phase IV, therefore, may need to focus back on the daily management practice in each of the departments in our areas.

In the past year, the program has certainly captured the attention, energy, and imagination of several people in our areas. For me, more than any one other activity, this program brings together the various strands that make up my responsibilities as a senior officer of M.I.T. in 1991. I believe that Building on Differences is one of the key elements of the agenda that will shape M.I.T.'s future.

Time and effort -- a good deal of effort -- will bring us to some point in the future where we will know better than we do now whether it is feasible at M.I.T. to achieve a more productive and satisfying work environment by building on the individual differences of our working colleagues. In my view, progress that will make a difference in this domain depends on leadership that is not singular but diffuse and pluralistic -- leadership that emanates from all levels of our organization. On behalf of M.I.T. and myself, I wish to thank the conveners and the consultants and every one of our colleagues who has exercised such leadership by taking part to date in the formative stages of our program.

CONSTANTINE B. SIMONIDES

Office of Admissions

For the second year in a row, colleges and universities across the country experienced declines in applications and yields (proportion of accepted students who enroll). The combined effect of the recession, cuts in financial aid, and the continuing decline in the number of college age students left many colleges with serious problems of underenrollment. However, the small group of most prestigious institutions, MIT included, did not experience the declines they experienced last year. Most held steady, and some, like MIT, had modest increases. I believe that all the national publicity last year about unfilled freshman classes caused some students to raise their aspirations toward the most select institutions.

We admitted fewer students this year in response to last year's increase in yield and resulting too large entering class. It appears at this point that the yield held steady and that we will be within a few students of our goal of 1050. It also appears that we will pass a milestone of some importance. Students who self identify as U.S. citizens or permanent residents and as either "Caucasian or other" will make up a minority (49%) of the entering class. MIT, on the forefront of most things, is anticipating in its students body the diverse U.S. population of the twenty-first century. This class will include the highest number of underrepresented minorities and the highest number of women in MIT's history.

We continued to reach out to members of the faculty to encourage their involvement in admissions. We held three sessions to invite faculty opinion on sample admissions cases and we encouraged departments to appoint faculty liaisons to the admissions office. Unfortunately, the sessions were poorly attended and fewer faculty members read folders. The only positive conclusion one can reach is that faculty members are relatively satisfied with the students being admitted.

ADMISSIONS FOLDER READING (# read by category of reader)

	87/88	88/89	89/90	90/91
Admissions Officers	9500	9200	8900	8700
Faculty	550	530	1000	700
Administrative Staff	4500	2800	1900	3000

We are moving forward in the development of a new generation of communication vehicles. Work has begun on a new admissions video, and we are preparing proposals for a revision of publications. This follows a year of reflection on our communication needs and of continued success in discovering ways to increase efficiency and reduce costs.

We completed, in cooperation with Administrative Systems Development, a major revision of all files and production programs associated with the data base. The conversion has been proceeding smoothly over the last week.

Our small experiment with shifting some fall recruiting travel to the spring met with success and we are planning a modest increase in spring travel.

Our program of recognizing secondary school teachers who have been cited by our admitted applicants as being especially influential entered a new stage. We identified the twenty or so teachers who have been named five or more times. We sent them a citation suitable for framing and a gift certificate to the MIT press.

We computerized the transfer process and revised all the literature for transfers and the application. We also participated in a meeting of transfer students at MIT and relevant administrators and identified a number of ways to better meet the needs of transfers. This resulted in earlier notification of the admission decision and a guarantee of housing. We also involved representatives from Course VI in order to better control the number of majors in that department.

After noticing an erosion in the yield of students admitted through the Early Action program, we instituted a successful program of follow-up. We also achieved success in targeting high ability women for special recruitment efforts. The yield of that highly sought after (i.e. admitted everywhere) group equalled the overall yield this year.

The number of applications from international students continues to grow (from 857 in 1989 to 1090 in 1991). We once again stayed within our quota by admitting only 85 (not including Canadians and Mexicans) and are enrolling 58.

The number of entering students requesting Advanced Placement Credit increase by 10% (from 822 to 906) and the number receiving credit increased 11%.

MICHAEL C. BEHNKE

ADMISSIONS TRENDS 1982 - 91

	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>
<u>Entrants from Secondary Schools</u>										
Preliminary applications	12,525	12,653	12,465	14,698	14,349	16,237	17,408	17,832	17,941	20,169
Final applications	5,921	5,959	6,055	5,747	6,213	7,372	7,437	6,698	6,426	6,481
Admissions offered	1,911	1,818	1,854	1,885	1,762	1,826	1,833	2,018	2,051	2,012
Actual registration to date	1,109	1,082	1,059	1,061	991	1,001	992	1,045	1,084	1,068*
Registrations as percent of admissions	57.5%	61.1%	57.1%	56.2%	56.2%	54.8%	54.1%	51.2%	52.9%	53.1%*
Number of secondary schools represented	842	891	722	860	830	848	844	867	867	866
Percent of students from 9 northeastern states	51.0%	50.5%	50.5%	44.7%	43.5%	39.8%	36.4%	32.5%	36.9%	37.3%
<u>College Transfers</u>										
Total applications	1,378	1,024	1,048	909	890	870	905	688	838	776
Applications completed	425	400	304	295	317	304	349	328	399	365
Admissions offered	118	128	124	131	137	106	141	103	118	80
Actual registrations	82	91	91	101	97	80	94	79	98	56*
Registration as percent of admissions	69%	71%	73%	77%	71%	69%	69%	77%	83%	70%*
<u>Graduate Students</u>										
Total applications	9,342	8,836	7,922	8,032	8,564	8,443	8,863	8,655	9,445	10,002
Admissions offered	2,920	3,007	2,223	2,467	2,457	2,243	2,101	2,549	2,378	2,338
Actual registrations	1,476	1,542	1,290	1,338	1,105	1,019	1,104	1,437	1,169	1,186*
Registration as percent of admissions	51%	51%	58%	54%	49%	45%	53%	56%	49%	51%*

*expected to register; actual number is not yet available (6/26/91)

Educational Council

The Educational Council included 1646 alumni/ae this past year, representing MIT in all 50 states, the District of Columbia, Puerto Rico, The Virgin Islands, and 44 foreign countries. This group included 298 women and 66 minorities (43 Blacks, 7 Puerto Ricans, and 16 Mexican-Americans). The Educational Counselors represented MIT at 270 local College Fair programs; they conducted 6272 admissions interviews, and held countless conversations with prospective MIT students and with local school personnel. Of all MIT applicants, 94.9 percent (98.2 percent within the United States) were interviewed by a local Educational Counselor.

Project Contact is a program which puts current undergraduates in touch with applicants, Educational Counselors, and school personnel. This past year 444 students, representing 133 different geographic areas (including 14 foreign countries), participated in this program run by the Educational Council Office.

Meetings for newly admitted students were held in 38 cities throughout the United States by Educational Council groups. Twenty-three of these meetings were held during MIT's spring break and I organized panels of current students to speak at each of these meetings.

MIT Open House Meetings were held throughout the United States in the fall. Local Educational Council members assisted members of the Admissions staff in arranging for 105 Central Meetings in 95 cities.

Another program supported by the EC office was the AMITA High School Visiting Program. Marti Ward ran this program, and coordinated the efforts of 80 volunteers, all women professionals (from AMITA, SWE, AWIS, AWM, or other women's professional organizations) to make 34 visits to 24 high schools throughout the Greater Boston Metropolitan Area. They spread the word to young women (and in some cases young men) about the importance of continuing to study math and science in order to keep career options open. A High School Visiting Program was run in Los Angeles as a joint effort with Cal Tech. The Los Angeles program had 90 volunteers (39 MIT alumnae) who visited 25 high schools.

The (somewhat out of date) MIT admissions videotape continues to be a popular medium. Requests for the tape came from 45 high schools, 10 Educational Counselors, 15 applicants, and 6 MIT offices.

The Educational Council Office, with the blessing of CUAFA (Committee on Undergraduate Admissions and Financial Aid) organized a high school award program to recognize high school juniors for outstanding achievements especially in the areas of mathematics and science. MIT alumni/ae and/or MIT Alumni Clubs could sponsor an award for \$25. The award winner received a certificate in a leather MIT case and a year's subscription to *Technology Review*. Seven awards were presented in this year's pilot program.

Bonny Kellermann resigned as Director of the Educational Council in mid-May. After having served over ten years in this position, she left to become Associate Registrar at MIT. A search is underway for a new Director.

BONNY S. KELLERMANN

Department of Athletics

OVERVIEW

The 1990-91 academic year has been one of effective consolidation for our Department on the heels of some relatively major changes of the previous year in restructuring faculty titles and promotion policy, in redirecting our Physical Education curriculum emphasis, and in reestablishing the necessary urgency and high priority for the 21st Century Facilities Upgrade Package to improve our increasingly uncompetitive MIT Athletic Facilities.

Highlighting the 1990-91 year of consolidation is the continuing growth in student participation, which reached three-year highs in virtually all program areas including physical education, intra-murals, club programs, and men's intercollegiates. Only women's intercollegiates show a slight dip in overall participation, which we expect to reverse in 1991-92 by the recently approved intercollegiate additions of women's lacrosse and women's track and field.

ACHIEVEMENTS OF MIT INTERCOLLEGIATE STUDENT ATHLETES

Over the last several years, our Department has stated frequently a central underlying theme of hope that because of all we provide athletically for our students, we will somehow minimize or totally prevent the unpleasant possibility that any prospective MIT student would decide to decline admission to MIT for some negative athletic reason. Put another way, we want all currently enrolled and prospective MIT students to have full knowledge and confidence that opportunities for athletic fulfillment and success at MIT are not only possible but a frequent reality.

The MIT student tends to reinforce his or her intelligence by being competitive, disciplined, and hard-working. Our athletic mission is to build on these strengths through the development of athletic skills and confidence supported by superior coaching leadership and an appropriate well-balanced schedule of opponents. With the proper management of this formula, the result is usually significant for considerable numbers of deserving students who gain athletic fulfillment and publicly acclaimed achievement. In turn, such publicity plus word-of-mouth examples of athletic success should reassure any prospective MIT student that athletic fulfillment is possible and even probable at MIT.

Certainly the most prestigious athletic award ever received by an MIT student was the selection of Yvonne Grierson, MIT Class of 1990 and a four-year swimming All-American, as the winner of the Honda Award as the Women's Division III Athlete of the Year. This award covers all sports and all 350 Division III institutions. The award was presented at the annual National Collegiate Athletic Association (NCAA) Convention.

Over the past two years, our MIT student athletes have arguably enjoyed more publicized athletic-academic recognition than any Division III institution in the United States and perhaps more than any intercollegiate institution except possibly Stanford, Harvard, and the University of Southern California. In the past two years, 28 MIT students have been named academic All-Americans by the College Sports Information Directors of America (CoSIDA) -- the highest two-year number among all 350 College Division II and III CoSIDA-member institutions. In 1990, William E. Singhose, MIT Class of 1990, now at Stanford in graduate school, was named the At-Large Team Academic All-American of the Year for his achievements in track and field.

Additionally, over the past two years, an unprecedented six MIT students have been named recipients of prestigious NCAA Postgraduate Scholarships. MIT's six winners represent the highest total of any college or university in the country over that period and represent an impressive breadth of MIT intercollegiate programs: football, track and field, men's and women's basketball, women's swimming, and men's tennis. Among the 1991 NCAA Postgraduate Scholarship recipients was Darcy D. Prather, MIT Class of 1991, who won just about every national award available including a Rhodes Scholarship and the Woody Hayes Award from the Ohio State University to the outstanding Division III scholar-athlete-community leader in the nation -- the second consecutive year that an MIT football

player won this coveted national award. Last year's Woody Hayes Award winner was Anthony Lapes, MIT Class of 1990.

Three MIT students who graduated in 1990 were winners of Eastern Regional awards and should be repeated here to properly round out the two-year picture. Both Bill Singhose and Yvonne Grierson, in addition to their national recognition, were named New England Division III Athletes of the Year. Additionally, Timothy R. Day (football and baseball) was named winner of the Eastern Collegiate Athletic Conference Award of Valor for his courage in defending a friend during a mugging and his comeback from stab wounds received during that defense to become a senior-year All-Conference athlete in both sports.

These awards are important to the undergirding of the constant MIT search for talented student leaders and to the enhancement of the student educational experience. But these awards do not just happen by the regular course of athletic events and media reporting. Rather, they happen to MIT students because Roger Crosley, our exceptionally talented and dedicated Sports Information Director, has maintained an unflagging philosophical emphasis and professional focus on the deserved recognition of MIT student athletes and on the diligent management of all the necessary details of fact finding and communication that finally result in such scholar-athlete award designations. Our students and the Institute are indeed fortunate to have Roger Crosley as our colleague, and I want to use this opportunity to herald his exceptional professional achievements for MIT.

OTHER HIGHLIGHTS OF THE 1990-91 YEAR

Under the leadership of Paul Grace, Coordinator of Sports Medicine and Equipment, our Department has effectively integrated two replacement assistant trainers into our sports medicine program while continuing to provide exceptional care to the MIT athletic community. Assistant trainers Jeanette Lane and Lisa Treadway have established themselves very quickly as superior professionals of dedication and skill who bring a valuable element of joy and good humor to their important work.

The successful transformation of the Department main office into a three-room "Office of the Director" has provided increased efficiencies and improved communications. I want to make particular mention of the strong leadership of recently promoted Administrative Assistant Laura Capone in making the transition such a smooth one. She has been ably supported by recently promoted Senior Secretary Pier Chacon and my new Administrative Secretary Melissa Cryder in the ongoing effectiveness of the new office structure.

Registrations in Physical Education have reached all time high levels for the fifth consecutive year with a total of 8,377 an increase of 689 registrations over last year. Fifty-five courses were offered in 1990-91, two more than the previous year. Aerobics classes continue to be the most popular offerings with Ropes/Team Building and Wellness the most important additions to the curriculum. We are optimistic that both additions will continue to increase participation in response to emerging student interest in these areas.

In response to Department recommendations supported by the Athletics Board, there has been formal approval for the addition of Women's Lacrosse and Women's Track and Field to varsity status in the MIT Intercollegiate Athletic Program. This brings the total number of MIT intercollegiate programs to 39. With these appropriate additions, we will continue to review our full complement of intercollegiate offerings remaining ever alert to the possibilities of "cost creep" through excessive program expansion.

The transition in Men's Track and Field Coaching leadership from Gordon Kelly to Halston Taylor appears to have gone smoothly. Gordon has continued as Director of Track and Field for men and women while Halston assumed head coaching responsibilities for men and Joe Sousa assumed responsibility for the women's cross-country and track and field programs. Men's participation and morale were at high levels, while the women had a sufficiently strong year to qualify for elevation to varsity intercollegiate status for the 1991-92 year.

FUTURE HIGH-PRIORITY OBJECTIVES

Complete the criteria for instructor-coach hiring and promotions with full understanding and consensus of the Department teaching/coaching faculty and senior administration.

Continue to develop the plans and financial support for the planned L-shaped 50-meter swimming pool and locker project. Other components of the project include a new enlarged weight room, additional team lockers in support of the Johnson Athletics Center, and a new complex of administrative offices. We plan to make a detailed report to prospective donors sometime in the fall of 1991, with a full plan of action ready for Visiting Committee review and support in March 1992.

Successfully integrate the newly designated intercollegiate programs of women's track and field and women's lacrosse into the MIT intercollegiate program mix.

Tighten the implementation of our Department cost-containment policy to avoid any repeat of the small budget deficit projected for 1990-91.

STAFF HIGHLIGHTS

We are pleased to note with considerable pride the recognition received by some of our MIT coaches:

- Men's tennis coach Jeff Hamilton was named New England Division III Coach of the Year.
- Baseball coach Fran O'Brien was named Coach of the Year in the Cape Cod Summer Baseball League. O'Brien was also ranked 34th on the list of wins by an NCAA Division III baseball coach (211 entering 1991).
- Heavyweight varsity crew coach Gordon Hamilton coached at both Olympic Sports Festival in Indianapolis, Indiana, and at the Goodwill Games in Seattle, Washington. Hamilton and freshmen heavyweight coach Stu Schmill ran a development camp for women's lightweight double sculls, which entered the World Championships.
- Football defensive back coach Vaughn Williams assumed a similar position with the Barcelona Dragons of the World League of American Football. Vaughn will return to MIT for the 1991 football season.
- Ice Hockey coach Joe Quinn won his 100th game at MIT.
- Former MIT tennis and squash coach Ed Crocker was inducted into the Squash Hall of Fame in February.

ROYCE N. FLIPPIN, JR.

Career Services and Preprofessional Advising

We started the year with the foreboding that it would be a difficult year for students entering the job market, but as in previous recessions MIT students fared remarkably well. In spite of tight times in many industries and in many parts of the country - not least in Massachusetts - few students came to us at year end saying that they were without a job. No doubt the MIT degree made a difference. No doubt other factors helped also: the flexibility of most MIT students with regard to geographic location, and their willingness to look at other options when their first choice proves unattainable. Among their other attributes, MIT students are realists.

The number of organizations recruiting through the Careers Office was down significantly from the year before, dropping from 477 to 382. They included 363 private companies and non-profit organizations and 19 government agencies. The figures compare with those for 1985-86, another recession year.

We have long observed that students scan the market less actively when they see fewer opportunities. So it was this year. The number of students having interviews dropped to 1,411 from 1,538 in 1989-90. They had a total of 9,144 interviews, down from 10,400 in 1989-90. It is likely that many students settled for employers with whom they had connections, through summer employment, previous full-time employment, or faculty contacts.

Those having interviews included 769 undergraduates, 380 master's and engineer's degree candidates, and 262 doctoral candidates. The PhDs were the only ones to turn out in larger numbers, responding to a gratifying interest in PhDs on the part of employers. While salary offers to bachelor's and master's degree candidates in most disciplines hardly moved up at all (losing ground in real terms) salary offers to PhDs rose faster than the inflation rate. The median offer in electrical engineering hit \$60,000.

Bachelors' salaries getting the strongest boost were those in chemical engineering, which rose over 8 percent, buoyed by strong demand from the oil industry. The median offer to bachelors in chemical engineering was \$38,400. The median for bachelors in computer science (Course 6-3) was \$35,800, in electrical engineering (Course 6-1) \$35,520, in mechanical engineering \$36,000, in management science \$34,500, and in civil engineering \$30,000. The highest offers to master's candidates in engineering went to electrical engineers, with a median of \$41,400. The median for masters in chemical, materials, and mechanical engineering was approximately \$40,000.

It was a difficult year for graduating architects. In past years we have hosted architectural career fairs at the Institute. This year, Elizabeth Reed, associate director with responsibility for advising students in architecture, kept the tradition alive by putting a new spin on it. With the purpose of staying in touch with the profession in Boston, and giving students the opportunity to talk with practising architects in their offices even if they had no jobs to offer, she persuaded 26 firms to open their doors to students during four days in April. Seventy-three students participated. As it happened, several students were offered positions.

Medical School

We do not have a final count of MIT candidates for medical school, but our preliminary statistics show exactly the same number as last year, 119. They include 95 undergraduate students, 5 graduate students, and 19 alumni. The number of undergraduates is up (from 76 in 1989-90); the number of graduate students and of alumni is lower. Typically, undergraduate students enjoy a higher acceptance rate than other candidates, so the total number of MIT candidates entering medical school this fall is likely to be up from last year. Last year 83 percent of MIT's undergraduate applicants were accepted.

Staff changes

Anne Armitage stepped down in August as associate director, recruiting, to give time to a new arrival in her family. Marianne Wisheart was promoted associate director in her place, with responsibility for recruiting. Bonny Hafner, previously with the School of Architecture, succeeded her as assistant director responsible for alumni career services and for advising students on study abroad.

ROBERT K. WEATHERALL

Medical Department

INTRODUCTION

A major focus for the Medical Department this year was preparation and fine tuning for the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) visit in October 1990. Thanks to the efforts of the entire staff we were well prepared and received full accreditation for the maximum period of three years. This external review of our patient care activities, quality assurance standards, safety features, medical records documentation, credentialing mechanisms and governance provides us with an objective evaluation and how we measure up to a set of standards applied to all hospital and ambulatory facilities in the country. I am particularly appreciative of the leadership provided by Bruce Biller, M.D. and Rochelle Alexander in organizing the full departmental effort.

As a department we have begun to look ahead to the next decade and beyond. As part of that process our intention is to stimulate others to generate ideas and activities that are generally reserved for those in higher positions of leadership and responsibility. This restructuring of the overall departmental planning began last year by involving members of the Medical Executive Committee in one of four task forces, in areas considered important for the vitality of the Department's patient care efforts, prudent management of financial resources and employee satisfaction. A retreat in April 1991, involving the Medical Management Board, the Medical Executive Committee and other task force participants, allowed a full report and articulation of ideas that will lead to setting priorities for future action. The task force areas encompassed: 1.) the future of the inpatient unit; 2.) student health care and health education; 3.) career development and; 4.) resources utilization and communication.

In addition to these four areas, we have recognized the need to address long range planning for care of elderly patients, upkeep of the physical plant, contributions to undergraduate education at MIT and to medical school teaching and hospital residency and fellowship training and developing shared activities with our upriver colleagues at Harvard University Health Services. All of these efforts will improve our ability to care for patients and to recruit the very best people for that task, which are our primary goals as a medical department.

MEDICAL CARE ACTIVITIES

Dental Service: Cynthia Stevens, D.D.S., Chief

The Dental Service, a busy service for the MIT community, has been limited in part by the shortages of personnel. New techniques to treat periodontal disease have been introduced which have led to a decrease in the need for surgical procedures. Ongoing activities include a study of the feasibility of a partial dental benefit for students or a reduction in student dental fees as well as an examination of the entire dental service operation by outside consultants representing expertise in a college setting and in the organization of a cost effective multiservice dental clinic. The dental staff has worked hard to educate people about preventive dental hygiene, and the overreaction to concerns regarding the toxicity of amalgam in dental work. A major aim of the service is to increase student care.

Medical Service: H. Walter Jones, Jr., M.D., Chief

In addition to providing personalized continuing care for members of the MIT community, the primary internal medicine staff has dealt with a variety of issues during this past year. Much of this activity has been in relationship to regular monthly meetings of the staff. Among these creative activities are the development of a statement summarizing the commitment of internists to their patients in the Department, issues of recruiting and retention of staff, expansion of nutrition services, the development of a new informed consent form for all procedures, an evaluation of our practices in ordering laboratory tests as well as discussions concerning the frequency of complete physical examinations for asymptomatic patients. Other changes have included FAXing of critical publications to members of the internal medicine staff, communications and procedures in securing consultations within the Medical Department, arrangements for urine drug testing, and following patients hospitalized at Mount Auburn or Massachusetts General Hospitals. We began an examination of scheduling practices through the Front Desk as well as communication with secretaries of individual physicians. A subcommittee is currently working on a reasonable solution to this problem. At the time of this writing Dr. Jones is anticipating retirement from clinical practice. His leadership role, which has been inspirational for the internal medicine group, will be handed over to Dr. Walter Rymzo commencing July 1, 1991.

Ambulatory and Off Hours Services: William A. Ruth, M.D., Coordinator

The Ambulatory Internal Medical Service experienced a five per cent increase in patient visits over a similar period last year including older patients with more complicated clinical problems. The Off Hours area continues to be competently staffed by the combination of nurse practitioners with primary care physicians and evening and overnight fellows from the Harvard affiliated teaching hospitals in the Greater Boston area. The number of visits to the Off Hours Service remains constant. Educational activities in the Ambulatory area include direct physician encounters, patient and chart reviews with primary care residents who are rotating through the service and ambulatory rounds held twice monthly in which the entire primary care staff participates. The majority of our staff physicians have participated in advanced cardiac life support courses, the latest one given this year at Harvard University Health Services. We also hope to develop a system for seeing students during the noon hour and to facilitate their visits in the late afternoon/early evening when classes have been completed for the day.

Inpatient Medical Service: Elaine L. Shiang, M.D., Physician Coordinator

A number of significant changes have marked the Inpatient Unit activities this year. New clinical services provided to patients included total parenteral nutrition, patient control analgesia, utilizing subcutaneous pumps for the control of pain, blood transfusions for individuals unable to easily be transported to neighboring hospitals and an ongoing evaluation of Inpatient Unit activities by one of the Department task forces. There will be a review of all patients who are in the Unit for longer than a month to evaluate the appropriateness of care in this facility. In addition increased utilization of the Unit by the Clinical Research Center for its study patients is being encouraged. These patients are undergoing metabolic and nutritional studies, neurologic testing and a variety of other long term investigations. The Inpatient Unit remains a flagship of the Medical Department and an area where we receive many letters of commendation.

Obstetrics and Gynecology Service: Charles F. Eades, M.D., Chief

Staffing remains an ongoing problem for the Service. We have secured the services of a number of physicians completing their residency training at Brigham and Women's Hospital as well as Dr. Martin Wingate and his colleagues at Mount Auburn Hospital. The number of patient visits exceeded 7500 this past year and there were 168 deliveries at Brigham and Women's Hospital, the percentage of births by Caesarean section remaining at three per cent which is a figure well within the norm. Infertility evaluations are conducted by Annie Liau, M.D. and Karen Halvorson, R.N.C. and we are developing new protocols for the evaluation and management of infertility patients. Counseling for miscarriages and other obstetrically related events continues to be done by the nurse clinician staff, in conjunction with the Social Services and Psychiatry Unit. We continue to diligently search for full time obstetrician/gynecologists.

Pediatric Service: Barbara L. O'Pray, M.D., Chief

The Pediatric Service sees a large number of children, adolescents and young adults. An increase in staff has made it possible to have two physicians and a nurse practitioner here during every clinic session, shortening the queues as well as allowing for urgent fit-ins. During this year 195 new babies were cared for by the Pediatric physicians at Brigham and Women's Hospital. Staff physicians also cared for numerous patients who were admitted to Children's Hospital. We continue to be active in the teaching of Harvard Medical Students, HST students and resident staff from Harvard affiliated hospitals. Staff members continue to be involved in teaching at the Brigham and Women's Hospital as well as in the Adolescent Clinic at Children's Hospital and at the Medical Inpatient Service at that hospital. We have an agreement to serve as a training site for adolescent fellows from the Children's Hospital Adolescent Program which is considered one of the prime programs of its sort in the country. This will allow individuals to gain experience in the field of college health and help us in recruitment efforts.

Psychiatric Service: Peter Reich, M.D., Chief

The addition of staff and a user friendly attitude has led to an increase in annual visits to the Psychiatric Service of approximately twenty five per cent compared to last year. This increase represents a larger number of visits per patient. The greatest increase in cases and in visits was in the undergraduate population reflecting greater acceptance of the Service by the undergraduate student body. Psychiatric admissions to the MIT Inpatient Unit were approximately the same as last year. There was a large decrease in the number of psychiatric hospital days. This decrease could be accounted for by a fall in student admissions and a drop in their total hospital days, the result of bringing students back to the Inpatient Service or to ambulatory care by a member of the Psychiatric staff.

The average length of stay in outside hospitals dropped by approximately ten days per admission reflecting both a general trend toward shorter hospitalizations and improvement in liaison between the MIT Psychiatric Service and outside facilities.

The Service launched an expanded training program during this past year with three postdoctoral psychologists, trainees and two senior psychiatric residents, all spending part time at MIT. Trainees saw patients for evaluation and therapy under individual supervision and also participated in educational and outreach programs which included outreach into living groups on campus. This program of part time trainees from other institutions will continue during the coming year and has greatly added to the ability to serve a larger segment of the MIT population. Additions to the psychiatric staff this year included Amy Brager, M.D. and Marcia Yousik, R.N.P., Clinical Specialist, our first psychiatric nurse clinician. These individuals have brought special clinical skills. The Service has been active in the HST program where Dr. Reich heads the student advisory system and teaches in an HST 230 course in "Real Medicine." Together with Dawn Metcalf of the Social Work Service, Dr. Reich has started a weekly cancer support group for MIT faculty, staff and dependents. Other members of the Department are much involved in MIT activities at large as well as Medical Department committees and other leadership responsibilities. Margaret Ross, M.D. was appointed Patient Advocate for the MIT Medical Department this year and has already distinguished herself in this position. The Psychiatric Service is beginning to look at psychiatric research opportunities at MIT working in areas such as the nature and prevalence of suicidal behavior.

Social Work Service: Ronald C. Fleming, LICSW, Chief

The Social Work Service remains principally a direct service provider of community mental health and medical social work services. In responding creatively and flexibly to community needs, the use of groups has been a major mechanism. During this year groups have included: 1.) parenting of adolescents; 2.) elder care support; 3.) Gulf support responding to families impacted by Desert Storm; 4.) graduate student parent group; 5.) cancer support; 6.) alcohol support. The Service also serves as a clearing house for self help organizations including those relating to substance abuse and overeating. Members of the Service also contribute to the environment of work, study and research at MIT by virtue of their participation in a variety of campus activities. The Institute Personal Assistance Program (IPAP) is the largest of such activities and during this year the IPAP was featured in TECH TALK. Minority Student Concerns Group and Summer Science Program at Lincoln Laboratory were other areas that were actively participated in by the Social Work Service. The Service has had a significant role in the "Building on Differences" program and on responding to the recent legislation for drugfree work force, drugfree workplace, drugfree schools and campuses. Elder care issues have been of growing concern. A "Perspectives on Aging" issue of the MIT HEALTH PLAN NEWSLETTER was developed by the Service and members of the Social Work group are interested and involved in further planning for the care of elderly patients.

Surgical Services: Stephen J. Healey, M.D., Chief

The contraction of the General Surgical Service by one member was effectively carried out through increases in planning and efficiency. This same effort was reflected in the operations of the Orthopedic Service where the number of staff orthopedic surgeons was reduced by one. These reductions related to a decrease in the demands for surgical and orthopedic surgical work.

Inpatient care of surgical patients remains an important function. Patients have been cared for with central intravenous lines and parenteral nutrition has been instituted in the Inpatient Unit for selected patients recovering from serious operations or deficits created by prolonged illness. Patients are often admitted to the Inpatient Unit on the same day following selected surgical procedures. We also continue to expedite early transfer of all surgical patients to the Inpatient Unit for their postoperative care where nursing is outstanding and where physician availability is of the moment.

Nursing Service: Janet V. Beyer, R.N., C., Maureen Dickey, R.N., Co-Chiefs

The combined efforts of the nursing staff were essential to prepare for the JCAHO visit. The Nursing Service has had a major role in working with the staff of the CRC in bringing into full activity the care of CRC patients in the Inpatient Unit.

A new position was created for a nurse clinician in the Psychiatry Department. In the Inpatient Unit there were changes in personnel which led to reorganization of scheduling. At Lincoln Laboratory Ms. Beyer continues to

coordinate Medical Department activities with the able assistance of Monique Cantin as the primary care practitioner. Several health screening sessions were held at Lincoln Laboratory as well as the first in a number of talks by members of the Medical Department relating to health activities of interest to the Lincoln Laboratory personnel. Other activities of the Nursing Service included a reorganization of Off Hours Clinic staff, precepting a pediatric nurse practitioner student, development of new infectious disease manual including updates on screening procedures for employees, instructions on universal precautions and instructions identifying individuals for immunization against hepatitis B and influenza vaccine.

OTHER DEPARTMENTAL ACTIVITIES

Clinical Research Center (CRC): Naomi K. Fukagawa, M.D., Associate Director

The CRC as part of the Medical Department was surveyed by the JCAHO during October 1990. Members of the CRC are represented on or report to the Medical Department Pharmacy, Quality Assurance, Medical Records and Safety Committees. In addition, Medical Department staff are members of the CRC Advisory Committee and attend weekly CRC staff meetings. Dr. Fukagawa was promoted to Associate Director and Dr. David August accepted the position as Assistant Director of the CRC. Research and educational activities continue to flourish with several UROP students and postdoctoral fellows participating in the research programs.

Environmental Medical Service (EMS): Alan M. Ducatman, M.D., Chief

MIT was without significant environmental health incidents. Initiatives by the Department of Energy, Nuclear Regulatory Commission, Environmental Protection Agency, Occupational Safety and Health Administration, and equivalent state agencies have increased substantially the regulatory burden at universities including MIT. We have coped with rapid changes largely because of significant institutional and faculty support. An expanding faculty role and increases in personnel will clearly be essential given the pressures from regulatory and funding agencies inputting on our operations and budget. Progress can be reported in previously identified goals which included 1.) Industrial Hygiene Office where a "template" OSHA Laboratory was completed in 37 of the 38 units where such oversight was essential; 2.) Radiation Protection Office has neared completion of major initiatives relating to design changes at Bates Linear Accelerator. In addition main campus waste disposal has been expedited and there has been an expansion of the planning efforts at the Plasma Fusion Center and Kwajalein atoll; 3.) Biohazard Assessment Office has trained approximately 500 MIT personnel concerning type handling of human tissue and blood-borne pathogens, as required by regulation; 4.) sampling demands for items such as asbestos and water purity have been accompanied by markedly increased regulatory requirements for extended quality assurance programs in industrial hygiene and radiation sampling. This resulted in an increase in eighty per cent in the number of asbestos samples, twelve percent in the increase in chemical analyses and exponential increases in water sampling activities during this year. With no overall environmental function there is a lack of coordinated approach to waste classes such as biological, chemical, radiation, asbestos, mixed recyclable, and bulk, the need for an office of environmental/waste affairs becomes more necessary.

Health Education Service (HES): Janet H. Van Ness, M.S.P.H., Coordinator

During this year the HES has been more visible than ever with a fifty two per cent increase in encounters. This number includes faculty, staff, student workshop participants, IAP attendees, individuals wishing to discuss health situations in private, individuals seeking hard to locate health information, students utilizing skills of peer education groups. The major areas in the program activities include; breastfeeding information and support program; the fourth annual "Aging Successfully" seminars organized by Katherine Stratton and the Honorary Matrons; the successful hosting of the Names Project AIDS memorial quilt with Institute-wide activities relating to the quilt's appearance and World AIDS Day, 1990; IAP, which attracted thirty per cent more participants than in the previous year; the growth in student health education related to the commitment and energy of full time health educator for students and the availability of this individual and her office within the Stratton Student Center; the "Social Midway" which attracted a minimum of 750 students and which promoted the concept of socializing without alcohol on campus and in the Greater Boston area; the addition of a diabetes support group to a number of peer education groups already active on campus; the institution of a telephone information line by the Women's Health Education Network to serve as a valuable resource for students of either sex and; the use of the student health resource center as an effective base of operations for student health operations programs.

Lincoln Laboratory Medical Clinic: Bruce J. Biller, M.D., Coordinator

The Lincoln Laboratory Medical Clinic is staffed by a number of nurse practitioners, physicians, and social workers. Patient education programs have been instituted including skin cancer screening and those programs both screening

and educational will be continued. Quality assurance monitoring is now in place in areas that include clinical management, work related injuries and patients requiring emergency care.

The clinic was included in the JCAHO survey and was felt to be in substantial compliance with standards. A patient satisfaction survey was conducted in order to help the Department's Lincoln Laboratory effort reach more people. A Lincoln Laboratory quality clinic group formed which will review clinic operations and identify opportunities to improve care. Linkages via phone and possibly television are being developed following a site visit to Kwajalein by the Medical Director.

Student Health Services (SHS): Mark A. Goldstein, M.D., Chief

International student health concerns continue to be a major focus of the Student Health Service and the Student Affairs Office. Programs now in development were presented at the National Meeting of the American College Health Association. Dr. Goldstein was awarded a grant by the National Association of Foreign Student Advisors to study international student information and attitudes towards AIDS. A survey questionnaire is currently under review and should lead to focused efforts in student health education.

In collaboration with the Dean's Office and the Housing Office free condoms are distributed to students. A training program was formally established with the Division of Adolescent Medicine at Children's Hospital to bring fellows in adolescent and young adult medicine to MIT supervised by the Medical Department. It is anticipated that these students, in addition to providing physician inputs in health care will also be involved in health education of the MIT student community; Dr. Goldstein chaired the task force on student health and health education that presented its findings after nine months of study and deliberation. Major recommendations were made in areas such as access to care, promotion of services, hospitalization policies, health education and the identification of the at risk student. A timetable for developing programs will span the next several years, a number of them implemented in time for September 1991 matriculation.

Efforts are being undertaken to promote the personal physician program of the Medical Department and to make our services more "user friendly." Reaching out to students who are at extraordinary risk and educating students on how to utilize the Medical Department facilities is an important part of this effort. Networking with the Dean's Office, Psychiatry Service, Housemasters and the Student Health Service should help to facilitate our efforts in this area. Programming involving peers as resources is in continuing development. Upgrading our communications sent to incoming students will include networking freshmen advisors.

Teaching and Clinical Education: J. Christian Kryder, M.D., Coordinator

We have continued to see an expansion of our educational activities in the Medical Department. Almost all of our staff physicians are now active at some level in teaching either at the medical student level or with medical residents/fellows. Approximately fifteen members of the staff act as premedical advisors to MIT undergraduates. The Mount Auburn Hospital/Harvard Primary Care Internal Medicine Residency Program has been expanded to include two junior and two senior residents receiving ambulatory training at MIT; Harvard Medical School/MIT Division of Health Science and Technology, Introduction to Clinical Medicine for Medical Engineering-Medical Physics Students participate in an intense eight week course which is taught by MIT Medical Department internists and pediatricians; Harvard/MIT HST Course 220, the Introduction to Patient Care Course, completed its third year; hospital-based teaching activities by MIT staff physicians continued at various area hospitals; and teaching conferences in the Medical Department continue to flourish.

Clinical Operations and Planning: J. Christian Kryder, M.D., Assistant Medical Director

Management activities over the past year have been divided among specialty and ancillary operations, management of health plan patients for outside services and Departmental planning. In the area of specialty and ancillary services there have been a variety of personnel and clinic structural changes in order to meet the needs of our patient population. The dermatology staff service has expanded. Orthopedics has become a referral service and has increased its capability to manage urgent problems despite contraction of personnel in that service. Due to increasing queues we have increased the amount of time devoted to otolaryngology consultations at MIT. Our health screening activities have shown an increase in certain testing, in particular, mammography and

echocardiography. Recently we have purchased a color flow instrument to expand the echocardiography technology. We have now secured equipment for providing cardiac exercise testing on site for low risk individuals. Finally, emergency services in the Medical Department were highlighted by a second advanced cardiac life support course, joint ventured with Harvard University Health Service. In the past year over three hundred medical and surgical admissions to outside hospitals were managed. The objective in managing these hospital admissions is to assure timely transmission of medical data and to be certain that hospital days are used efficiently. As part of a strategy to manage services more efficiently we are currently looking at ways in which we may improve the Department's care of medical and psychiatric patients which would reduce these hospital days for people cared for in the Department. Planning represents another major area of activity. As noted earlier, the four specific areas of planning that were mandated in the development of task forces by the Department underwent focused review by Executive Committee members as well as others. The objective of this process is to ultimately decentralize planning, to involve chiefs of service on a direct and ongoing basis in the affairs of planning. These groups reported their findings to a joint meeting of the Executive Committee and the Medical Management Board this year and the issues presented have now been prioritized and goals for implementation of many recommendations have been set. Overall planning within the Department will be advanced by enhanced data collection that began in July 1990. With a year of more complete information regarding individual physician practices and patient utilization patterns we hope to provide a foundation for assuring more efficient and effective delivery of high quality services within the Department. Staying abreast of regulatory and legislative issues has been a major effort of Dr. Kryder and Executive Director, Linda Rounds. This past spring Dr. Kryder became Vice Chairman of the Massachusetts Association of HMO Directors Advisory Group which should facilitate the sharing of vital information in this area.

MIT Health Plans, Linda L. Rounds, Executive Director

At the present time, there are about 7,700 members enrolled in the Traditional MIT Health Plan and about 2,000 members in the Flexible MIT Health Plan. The introduction of the Flexible MIT Health Plan in 1989 allowed us to increase our total enrollment by about 1,000 members overall, but, most importantly, has helped us maintain our market share during a period of intense competition among HMO's. Of the 8,400 MIT employees selecting health insurance, approximately 49% (4,100 employees) are enrolled in either the Traditional or Flexible MIT Health Plan. This high market penetration is quite remarkable given the intensity of the HMO competition. At MIT, however, the next leading shares of the market are held by HCHP and Baystate Health Care, with each having only approximately seventeen per cent of those employees selecting health insurance through MIT. Our position in the market continues to be enhanced by our ability to provide access and quality care at a reasonable cost. Patient satisfaction, as expressed by the very low level of voluntary disenrollments (less than two per cent of the total subscribers in 1990), is high. Fortunately, the Plans' financial results have been within budget despite the changing demographics of our membership. We are optimistic about the future, and a twenty year anniversary celebration. The pressures of costs, demography and competition are intense, but by working together we will continue to be able to offer high quality health care to the MIT community at a reasonable cost.

Personnel Changes

The following changes occurred for Administrative and Academic Staff during the period June 1, 1990 through June 30, 1991.

APPOINTMENTS

Nancy R. Blum	Clinical Psychologist
Amy R. Brager	Psychiatrist
Allen J. Brown	Clinical Psychologist
M. Linda Brown	Physician
Richard S. Clement	Assistant Radiation Protection Officer
Elizabeth J. Connor	Inpatient Nurse
Joan M. Corr	Postdoctoral Fellow, Psychiatry
David V. Diamond	Physician
Thomas Fuller	Assistant Radiation Protection Officer
Barbara A. Goff	Obstetrician/Gynecologist
Kristin Graham	Obstetrician/Gynecologist
Patricia B. Grimes	Dental Hygienist

Marilyn F. Hallock	Industrial Hygienist
Richard D. Krikorian	Gynecologist
Yolette G. Lecorps	Assistant Supervisor, Medical Records
Kathleen L. Marshall	Assistant to Executive Director
Eliza W. Menninger	Postdoctoral Fellow, Psychiatry
Janet C. Moses	Pediatrician
Michael T. Myers	Physician
Elizabeth Petrow	Clinical Psychologist
David I. Sachs	Network Engineer
Deying Sun	Health Physicist
Nancy Teiger	Nutritionist
Raina Trilokekar	Dentist
Martin Wingate	Gynecologist
Marcia Yousik	Psychiatric Nurse Practitioner

RESIGNATIONS/RETIREMENTS/CHANGES

Constance A. Bean	Coordinator of Health Education (Retired)
Nancy R. Blum	Clinical Psychologist
Allen R. Brown	Clinical Psychologist
Linda Y. Buchwald	Neurologist
Stephen S. Falkenberry	Obstetrician/Gynecologist
Margaret L. Forsyth	Physician
Cyril Gaum	Dentist
Barbara A. Goff	Obstetrician/Gynecologist
Kristin J. Graham	Obstetrician/Gynecologist
H. Walter Jones, Jr.	Physician Emeritus (Change)
Alfred J. Koumans	Psychiatrist (Retired)
Aaron Menzin	Psychiatrist
Elizabeth A. Stewart	Obstetrician/Gynecologist
Carol A. Tereskiewicz	Physician
Susan L. Warren	Postdoctoral Fellow, Psychiatry
Matthew J. Weintraub	Surgeon
Grace Lim Wong	Nutritionist

Concluding Comment

The Medical Department is healthy and we are working hard to maintain our vigor and competitive edge in the face of significant pressures effecting the costs of health care services. At home we have been able to keep costs down while providing quality services. However, outside hospital and procedure expenses and rising prices of pharmaceuticals are constant threats to solvency and demand ongoing efforts on the part of every member of the Department. We are not ignoring future needs as we work to maintain present services. The recommendations of the Department task forces have shaped efforts that will help us fiscally, that will give us a competitive advantage in recruitment of personnel, that focuses on the needs of all students, including internationals, and mandate creative utilization of our precious inpatient resource.

Leadership must eventually rest with one individual, but special recognition and thanks must be given to the individuals who work closest with me, Linda Rounds, Executive Director, Dr. Michael A. Kane, Associate Medical Director and Dr. J. Christian Kryder, Assistant Medical Director.

ARNOLD N. WEINBERG, M.D.

Fiscal 1991 was a year of solid sales growth in a depressed publishing environment severely affected by inordinately high book returns, flattening text sales, and tight academic, library, and research budgets for monograph purchasing.

This recession in the market comes just at the peak of the realization of the Press's expansion plans. Our overall program, including books produced from original manuscripts as well as co-publication and imports has according to plan, grown significantly over the past two years, requiring substantial growth in both plant and printing costs, raising our need for borrowed capital from M.I.T. Interest charges have grown from \$52,000 in Fiscal 1990 to \$143,000 in Fiscal 1991.

Actual sales were \$11,660,000, or 14.2 percent higher than in Fiscal 1990. There was a shortfall of about \$500,000 from our reforecast due to the conditions described above -- a situation experienced by most of the university presses as well as the industry as a whole. The shortfall and high returns exacerbated the impact of high borrowing to support growth. The results were a deficit for operations of (\$294,000) plus an interest charge of \$143,000, for a total deficit of (\$437,000). Investment income was \$144,000, and the bottom line charged against our reserve was (\$293,000). This compares with (\$172,000) for Fiscal 1990. RA/TA costs contributed approximately \$275,000 to our operating costs last year.

International sales were 33 percent of total, a \$663,200 increase over last year.

At the same time, a majority of our core publishing programs has blossomed in Fiscal 1991, with high levels of excellence evident in the list at all levels. Fiscal 1992 promises a continuation of this momentum in quality and depth. Our aggressive marketing programs both here and abroad will continue apace in support of this growing list. At the same time, to address the shortfall during the last two years, we have instituted a program of cost savings as well as a reexamination of our book budgeting/scheduling processes, our pricing schedules, inventory levels, import and translations program, and travel expenses.

Bestsellers from the Fiscal 1991 list included:

Akmajian et al.	<u>Linguistics, 3d edition</u>
Barlow	<u>From Gaia to Selfish Genes</u>
Becher	<u>Blast Furnaces</u>
Crary	<u>Techniques of the Observer</u>
Dreyfus	<u>Being-in-the-World</u>
Goldsmith et al.	<u>Imperiled Planet</u>
Johnson	<u>Frank Lloyd Wright vs. America</u>
Klein	<u>The Atheist & the Holy City</u>
Kurzweil	<u>The Age of Intelligent Machines</u>
Leebaert et al.	<u>Technology 2001</u>

MIT authors:

Diamond et al.	<u>Growth/Productivity/Employment</u>
Dietz	<u>Dwelling House Construction, 5th edition</u>
Fisher	<u>Industrial Organization, Economics, & the Law</u>
Grimson	<u>Object Recognition by Computers</u>
Kearns	<u>The Computational Complexity of Machine Learning</u>
Kilian	<u>Use of Randomness in Algorithms & Protocols</u>
Meyer et al.	<u>Research Directions in Computer Science: An MIT Perspective</u>
Papadopoulos	<u>Implementation of a General Purpose Dataflow Multiprocessor</u>
Taylor et al.	<u>Socially Relevant Policy Analysis</u>
Tester et al.	<u>Energy & Environment in the 21st Century</u>

Among the noteworthy books by non-MIT people from our scholarly and professional program were:

Ait-Kaci	<u>Warren's Abstract Machine</u>
Ayache	<u>Artificial Vision for Mobile Robots</u>
Black	<u>Information in the Brain</u>
Blelloch	<u>Vector Models for Data-Parallel Computing</u>
Bromberg	<u>The Laser in America, 1950-1970</u>
Canzoneri	<u>Monetary Policy in Interdependent Economies</u>
Cinque	<u>Types of A'-Dependencies</u>
Cohen	<u>Cognition through Color</u>
Friedman	<u>About Time</u>
Grimshaw	<u>Argument Structure</u>
Hall	<u>The Rational Consumer</u>
Hornstein	<u>As Time Goes By</u>
Hunter & Bryant	<u>A History of Industrial Power in the U.S., vol. 3:</u>
Jackendoff	<u>Semantic Structures</u>
Katz	<u>The Metaphysics of Meaning</u>
Kim	<u>Introduction to Object-Oriented Databases</u>
Lightfoot	<u>How to Set Parameters</u>
MacKenzie	<u>Inventing Accuracy</u>
McCarthy	<u>Ideals & Illusions</u>
Parsons	<u>Events in the Semantics of English</u>
Perner	<u>Understanding the Representational Mind</u>
Pugh et al.	<u>IBM's 360 & Early 370 Systems</u>
Sutton	<u>Sunk Costs & Market Structure</u>
Wellman	<u>The Child's Theory of Mind</u>
Zuidervaart	<u>Adorno's Aesthetic Theory</u>

New hardcover books for trade and general audiences included:

Ackerman	<u>Distance Points</u>
Agrest	<u>Architecture from Without</u>
Aspray	<u>John von Neumann & the Origins of Modern Computing</u>
Barlow	<u>From Gaia to Selfish Genes</u>
Becher	<u>Blast Furnaces</u>
Bois	<u>Painting as Model</u>
Collins	<u>Artificial Experts</u>
Crary	<u>Techniques of the Observer</u>
Cuff	<u>Architecture: The Story of Practice</u>
Delaporte	<u>The History of Yellow Fever</u>
Goldsmith et al.	<u>Imperiled Planet</u>
Hausen et al.	<u>Eliel Saarinen Projects, 1896-1923</u>
Johnson	<u>Frank Lloyd Wright vs. America</u>
Klein	<u>The Atheist & the Holy City</u>
Kurzweil	<u>The Age of Intelligent Machines</u>
Le Corbusier	<u>Precisions</u>
Leebaert et al.	<u>Technology 2001</u>
Mendelson	<u>Becoming a Brother</u>
Nye	<u>Electrifying America</u>
Rowe	<u>Making a Middle Landscape</u>
Sproull & Kiesler	<u>Connections</u>
Tzonis	<u>Hermes & the Golden Thinking Machine</u>
Zizek	<u>Looking Awry</u>

Books published primarily as texts included:

Akmajian et al.	<u>Linguistics, 3d edition</u>
Banker & Goslin	<u>Culturing Nerve Cells</u>
Benhabib & Dallmayr	<u>The Communicative Ethics Controversy</u>
Boyd et al.	<u>The Philosophy of Science</u>
Carriero & Gelernter	<u>How to Write Parallel Programs</u>
Dreyfus	<u>Being-in-the-World</u>
Mankiw & Romer	<u>New Keynesian Economics</u>
O'Keefe	<u>The Craft of Prolog</u>
Smith	<u>An Introduction to Text Processing</u>

Editors in the Acquisitions Department include: Laurence Cohen (Linguistics, Philosophy, Technology Studies); Roger Conover (Architecture, Design Arts); Terry Ehling (Computer Science, Artificial Intelligence); Robert Prior (Computer Science, Artificial Intelligence); Henry and Elizabeth Stanton (Cognitive Science); Fiona Stevens (Neuroscience); and Terry Vaughn (Economics).

BOOK PRODUCTION

Under the direction of Helene Osborne, managing editor, and Terry Lamoureux, production manager, the editorial and production departments continued to add quality to our publications. The design department, under Yasuyo Iguchi upheld the Press tradition of award-winning jacket and book design, garnering honors from the New England Book Show, the Association of American University Presses, the Creative Club of Boston Show, Print Magazine, The American Institute of Graphic Arts, and International Design Magazine.

COMPARATIVE OPERATING RESULTS (in thousands)

	Fiscal Year 1991 Actual	Fiscal Year 1990 Actual	Fiscal Year 1989 Actual
Total Net Book Sales	\$ 11,660	\$ 10,207	\$ 9,706
Cost of Sales	<u>5,340</u>	<u>4,580</u>	<u>4,242</u>
Gross Margin on Sales	6,320	5,627	5,464
Other Pub. Income	174	164	127
Bookstore Net	<u>120</u>	<u>110</u>	<u>95</u>
Total Income	6,614	5,901	5,686
Operating Expense	<u>6,907</u>	<u>6,273</u>	<u>5,745</u>
Net Books Division	(293)	(372)	(59)
Journals Net	<u>(1)</u>	<u>84</u>	<u>42</u>
Net Operations	(294)	(288)	(17)
Add: Investment Income	144	168	162
Deduct: Interest Paid MIT	<u>(143)</u>	<u>(52)</u>	<u>(28)</u>
Net to Reserve	(293)	(172)	117

Faculty serving on The MIT Press editorial board in 1990-1991 were Professors Harold Abelson, Stanford Anderson, Penny Chisholm, John P. Longwell, Peter Diamond, Jay Lucker, Albert Meyer, Josh Cohen, Dan Osherson, Merritt Roe Smith, Robert Silbey, and Robert Solow. Jay K. Lucker, Constantine B. Simonides, and Frank Urbanowski served as ex-officio members. Professor Robert Solow served as chairperson of the editorial board.

The MIT Press management board met once during the year. Members of the board are Robert M. Solow, Professor in the Department of Economics; Ellen T. Harris, Associate Provost for the Arts and Professor of Music; Jeremiah Kaplan, President of Macmillan Publishing Co., Inc.; W. Bradford Wiley, Chairman, John Wiley & Sons, Inc.; Jerome S. Rubin, Group Vice President of Times Mirror; Thomas L. Magnanti, Professor, Management Science and Area Head, Sloan School Of Management; Steven R. Lerman, Professor in the Civil Engineering Department; and Jack Schulman, former Director of the Cambridge University Press. Frank Urbanowski, Director of The MIT Press and Constantine Simonides, Vice President in the Office of the President, are ex-officio members and Robert Solow is chairperson of the management board.

BOOK PROGRAM

The strength of our core lists continues to grow. These lists -- art and architecture, economics, computer science, cognitive science and linguistics, and philosophy account for about 87 percent of our total sales in this last fiscal year.

BOOK SALES

Customer Type	Fiscal Year 1988	Fiscal Year 1989 (in thousands)	Fiscal Year 1990
College Bookstore	\$ 1,501	\$ 1,781	\$ 1,959
Retail Bookstore	1,774	2,225	2,071
Wholesaler/Jobber	1,750	1,844	2,017
College/University Library	164	130	135
Direct Mail	584	512	509
To Individuals	<u>755</u>	<u>880</u>	<u>951</u>
TOTALS	6,527	7,373	7,641

The Press had a modest 5.2 percent increase in sales this last year. Unit sales also increased slightly by about 1 percent. Total sales were \$10,206,900, 31 percent of which was outside the United States. The other bright spot is in the area of text sales, which increased about 10 percent in Fiscal 1990.

INTERNATIONAL SALES

Book sales to countries outside the U.S. grew almost 21 percent in Fiscal 1991. The largest increase in the major export markets (the top four rows in the table below) was posted by the London marketing office, which is responsible for sales to the U.K. and Continental Europe. Their dollar income rose 26 percent and total sales reached £1,000,000 for the first time. The many smaller markets which make up the "Other" category in the table achieve a 33 percent gain despite the total cessation at mid-year of sales to India -- the result of draconian import regulations imposed by the government of India. Korea led the way, rebounding dramatically from a weak F1990 with a 131percent jump in purchase of MIT Press books, to over \$63,000. Latin America at last showed signs of economic progress, with sales increasing by 55 percent to over \$35,000.

	International Book Sales FY 1989 - 1991		
	Fiscal Year 1991	Fiscal Year 1990	Fiscal Year 1989
Australasia	\$ 181,400	\$ 161,500	\$ 122,000
Canada	558,600	509,600	409,500
Japan	613,700	551,300	450,900
UK/Continent	1,891,800	1,502,500	1,365,700
Other	<u>580,000</u>	<u>437,600</u>	<u>352,500</u>
TOTAL EXPORT	\$ 3,825,700	\$ 3,162,500	\$ 2,700,000
percent of total sales	33.2	31.8	28.7

SUBSIDIARY RIGHTS

Our subsidiary rights program continues centered on the sale of translation rights. Income in Fiscal 1991 increased by 5 percent over income in this category in Fiscal 1990. The market economic recession of the past year and the rapid political and economic changes in Eastern Europe have created an atmosphere of caution across the publishing industry. However, our list continues to grow in visibility and importance both domestically and continues to grow in visibility and importance both domestically and abroad. While foreign publishers are conservative in their purchases and the size of the advances offered, sales of translation rights continue to take place at an even rate.

This year's income derived from English language reprints increased by 3 percent over Fiscal 1990. As expected, income in this category has stabilized with the streamlining of our permissions procedures and the elimination of the backlog that accumulated before a permanent employee was assigned to this job. The recent court decision against unauthorized copying has generated a great deal of permission requests, and it's likely that this will translate into additional income in the coming year.

The amount derived from sales to book clubs increased by 86 percent in Fiscal 1991 over Fiscal 1990. Over the past year, book clubs have become increasingly consolidated and competitive; in response to economic pressures, their editorial policy seems to be shifting toward less specialized titles. Projections in this category, therefore, continue to be speculative, although we continue to maintain a strong relationship with the book clubs we sell to most often particularly Newbridge's Library of Science. A small but unexpected sales to Book of the Month Club (Krugman/THE AGE OF DIMINISHED EXPECTATIONS) could indicate a niche in the book club market for policy-oriented books.

Total subsidiary rights income increased by 13 percent in Fiscal 1991.

Subsidiary Rights Income FY 1989 - FY 1991
Fiscal Year 1991 Fiscal Year 1990 Fiscal Year 1989

Translation Rights	\$ 155,042	\$ 148,132	\$ 104,998
Book Club Rights	48,458	25,986	61,281
Reprint Rights	67,801	61,281	29,499
Audio Visual	<u>1,000</u>	<u>200</u>	<u>1,400</u>
	\$ 272,301	\$ 240,042	\$ 197,178

PROMOTION, PUBLICITY, AND DIRECT MARKETING

A roller-coaster year in text sales. Reflecting an industry-wide fall-off in text sales MITP sales (which were 12.6 percent above last year at the end of October) dipped down to a final year total of \$2,149,000, or \$11,000 below Fiscal 1990. Interestingly, unit sales were down a dramatic 10 percent, indicating that we sold fewer books, with higher prices. New titles contributing to sales include new editions of Akmajian/LINGUISTICS, Goudi/THE HUMAN IMPACT ON THE NATURAL ENVIRONMENT, Churchland/MATTER AND CONSCIOUSNESS, and Pursell/TECHNOLOGY IN AMERICA. Recent titles with a promising future include Baker/ENGLISH SYNTAX, Chierchia/MEANING AND GRAMMAR, Forester/COMPUTER ETHICS, and Krugman/THE AGE OF DIMINISHED EXPECTATIONS. Backlist contributors included strong sales for Biermann/GREAT IDEAS IN COMPUTER SCIENCE, Blanchard/LECTURES ON MACROECONOMICS, and Tirole/THE THEORY OF INDUSTRIAL ORGANIZATION. We suffered particularly high returns this fiscal year. Two titles showed strong sales in the first quarter and almost equally strong returns in the last two quarters, Adams/BEGINNING TO READ, and Dertouzos/MADE IN AMERICA.

Direct mail traceable sales were \$586,300, up a gratifying 15.6 percent from last year. Unit sales (23,800) were up 5.4 percent. For the second year in a row the economics catalogs produced over \$90,000 in total sales, followed by computer science, cognitive science, art and architecture, neuroscience, linguistics, and philosophy. The annual clearing sale produced the highest income in three years, \$190,100, up 45 percent from Fiscal 1990 and 43.6 percent from Fiscal 1989.

Advertisements for MIT Press books appeared in 334 trade and scholarly journals and magazines, as well as conference programs. In an effort to bring advertising production in-house, 264 (77 percent) of those ads were created on the Macintosh computer. The advent of a high resolution scanner has made it possible to reproduce art and book jackets for use in advertisements, greatly reducing the cost of overall production.

The net contribution to sales from the Exhibits Program was \$94,900 with another \$5,000 in orders expected from meetings held at the end of the fiscal year. Held locally at the Hynes Convention Center the Artificial Intelligence meeting was a standout, generating \$25,000 in sales for press books.

MIT Press titles were reviewed or featured in a variety of trade and scholarly publications during the 1990-1991 season. Perhaps most newsworthy was MIT Professor Paul Krugman's *The AGE OF DIMINISHED EXPECTATIONS*, which appeared on *The Washington Post's* bestseller list and was reviewed in *the New York Times Book Review*, *the Wall Street Journal* and major daily newspapers across the country. *Business Week* and *Inc. Magazines* featured the book and author, and included the title in their respective Top Ten Business Books of 1990 lists. Krugman made appearances on NBC-TV's "Today Show," *The World Monitor* television network, and various radio talk shows.

THE AGE OF INTELLIGENT MACHINES by inventor Raymond Kurzweil, won the American Association of Publishers "Most Outstanding Computer Science Book of 1990." *BEGINNING TO READ* by Marily Adams was featured in a special education edition of *Newsweek* and covered widely in the education journals. A syndicated column praising the book ran in several major newspapers.

Susan Wright's *PREVENTING A BIOLOGICAL ARMS RACE* has received considerable review attention in science journals: *Nature*, *New Scientist*, *Science*, *Science Books and Films*, as well as through syndicated newspaper columns.

Many MIT Press art and architecture titles were featured in holiday giftbook round-ups published by newspapers across the country.

Awards won by MIT Press publications: Society of Architectural Historians Alice Davis Hitchcock Award - Anthony Vidler/*CLAUDE-NICOLAS LEDOUX*. Eccles Prize for Excellence in Economics Writing -- Paul Krugman/*THE AGE OF DIMINISHED EXPECTATIONS*. American Institute of Architects Book Award (3-way tie) -- Anthony Vidler/*CLAUDE-NICOLAS LEDOUX*, Marika Hausen, *ELIEL SAARINEN*, and Edward Ford, *THE DETAILS OF MODERN ARCHITECTURE*.

JOURNALS

In FY91, the Journals Division had gross sales of \$2.5 million, a 4 percent increase over last year. \$93,600 was added to the deferred subscriptions reserve account, a 9 percent increase. New total reserve at year end was \$1,093,000. The two journals joining the program in mid-year -- *THESIS ELEVEN* and *DESIGN BOOK REVIEW* -- had a combined loss of \$73,712, contributing to the Journals net loss of \$945. Last year's surplus of \$83,600 included receipts from the sale of the publication *MATERIALS AND PROCESSING REPORT*.

The division ends the year publishing twenty-three journals. The others are: *ASSEMBLAGE*, *COMPUTATIONAL LINGUISTICS*, *COMPUTER MUSIC JOURNAL*, *DESIGN ISSUES*, *DESIGN QUARTERLY*, *THE DRAMA REVIEW*, *THE ECOLOGIST*, *JOURNAL OF INTERDISCIPLINARY HISTORY*, *INTERNATIONAL ORGANIZATION*, *INTERNATIONAL SECURITY*, *JOURNAL OF COGNITIVE NEUROSCIENCE*, *LINGUISTIC INQUIRY*, *MIMAR*, *NBER MACROECONOMICS ANNUAL*, *NEURAL COMPUTATION*, *OCTOBER*, *QUARTERLY JOURNAL OF ECONOMICS*, *THE INTERNATIONAL JOURNAL OF SUPERCOMPUTER APPLICATIONS*, *THE INTERNATIONAL JOURNAL OF ROBOTICS RESEARCH*, *TAX POLICY AND THE ECONOMY*, and *THE WASHINGTON QUARTERLY*.

FRANK URBANOWSKI

Personnel Office

This was a year of maintenance, with the one major initiative being the beginning of the process of implementation of the new human resource information system approved by the Administrative Computing Steering Committee. We have contracted with an information systems consultant to perform as project manager for a two-year period and are moving cautiously to install a system to better meet the needs of the community as well as our internal needs.

In 1989, at the time of the merging of the two retirement plans to become the MIT Retirement Plan, enhancements to the pensions of many of our retired members were approved. The major programming effort needed prior to and following implementation of the merging of the plans impacted on our ability to provide the increases at that time. We are delighted to report that the authorized changes were put into place this year, thanks to major efforts by members of the Benefits Accounting Office.

Providing benefits information to the community continues to be a formidable task, as benefit program design becomes more complex in part because of external regulations. There is much discussion about the rapidly rising cost of providing health care insurance and in managing health care costs while assuring that employees have quality care available to them.

The overall decline in the economy has served to increase the number of people seeking employment opportunity, while at the same time we have had considerably fewer openings. The Personnel Officers and their staffs have felt the burden of applicants' frustrations.

The Office of Special Community Services was formed this year, reporting to the Director of Personnel and incorporating the Child Care Office, the Quarter Century Club with its activities, and the MIT Activities Committee (MITAC). Funding has been approved to appoint a person to manage these various services and to add other appropriate services in response to needs articulated in the report of the Family and Work Committee. A search is underway to identify a manager to fill the position.

Cynthia L. Vallino was promoted from Personnel Officer to a newly created position, Assistant to the Director of Personnel and has been working in that capacity since September. Alyce Johnson was hired as Ms. Vallino's replacement. Other staffing changes include Carl Whitaker who transferred from the Benefits Office to the Benefits Accounting Office and Judith DeCoursey who moved out of state. Other staffing changes are noted in the section reports; however, I must take the opportunity to report that Michael J. Parr, an Institute employee of 23 years and Assistant Manager of Labor Relations, resigned his position to enjoy a different way of life after picking a winning number in the lottery. We thank Mike for his devoted hard work during his years here and wish him well.

As of June 30, 1991, of the total of 26 administrative staff members, 5(19%) are underrepresented minorities and 20(77%) are women. (In 1990, these figures were 3(12%) and 18(69%) of 26).

As of June 20, 1991, the number of underrepresented minorities on the Support Staff is 4(19%) of a total staff of 25. (In 1990, the figure was 4(20%) of 24)

JOAN F. RICE

COMPENSATION OFFICE

The mission of the Compensation Office is to provide fair and equitable salary administration for each of the Institute's five payroll groups. The work performed by our office is interesting and diverse, and involves continuous interaction with a broad spectrum of the MIT community. We consult with Senior Officers, Department Heads and Managers, as well as a wide cross section of supervisory and non-supervisory personnel. Our activities focus in the following major areas: design and implementation of major national salary surveys; analysis of survey data; preparation of recommendations for annual review allocations to the Executive Committee of the Corporation; implementation and analysis of annual reviews; development, modification and maintenance of the Institute's two job classifications systems; monitoring of all payrolls for salary equity; and the preparation of numerous special studies and statistical reports.

It is difficult to describe the contribution of our office simply by citing numbers. However, the following statistics are interesting, and give a sense of the scope of our activity in some of our major areas of responsibility.

We conducted two national annual surveys, one relating to Faculty salaries, and one to Administrative Staff salaries. These surveys involved collecting data from approximately sixty universities and businesses across the country. The participants in these surveys reported data for approximately 24,000 faculty and staff members. These data were combined and analyzed, and appropriate summaries were returned to each of the participants. In addition to these two MIT surveys, we submitted data to approximately 39 outside surveys.

We conducted nine, separate, annual salary reviews covering approximately 8,300 members of the Institute's faculty and staff.

We reviewed a total of 132 individual requests for reclassification in the Institute's Staff Classification Program, including 54 requests to assess newly created positions, and 78 promotional requests and requests to reevaluate existing positions.

We continued to make progress during the year in developing personal computer systems to support our various activities. For example, most of the outside organizations that participate in our two national salary surveys now submit data on diskettes. We have developed a number of spreadsheet and database applications that facilitate the input and analysis of these survey data. We have also developed similar personal computer support systems that automate the analysis and record-keeping functions associated with the Institute's classification programs and annual reviews, including a number of "macro-driven" spreadsheets.

In closing, I would like to thank my three immediate associates for their unstinted hard work and good spirits. It would be hard to imagine trying to accomplish all that we do without Susan Lester's abundant energy and good counsel, or the outstanding support and friendship of our colleagues, Dineen Doucette and Judy Raymond.

KERRY WILSON

BENEFITS OFFICE

This year the Benefits Office was able to work through a regular annual cycle of benefits administration without major design or legislated changes that had to be implemented. There was more on-the-job and team meeting training than the structured classroom training of the past two years. This was primarily attributable to the successful development of the staff over the past two years.

Changes in the Long Term Disability Plan were announced and implemented. Thomas L. Jacobs & Associates was selected as the third party administrator to adjudicate claims. The plan is now self-insured for all claims beginning after August 31, 1990.

This year we did not conduct as many community information meetings as in the past, but we did accommodate requests for presentations to departments and other small groups. Some of these presentations focused on a particular benefit, while others were more general discussions of the MIT benefits programs.

The Office has been working with the Personnel Officers and Administrative Officers to identify needs and areas of improvement and to implement corresponding changes. An additional focus of these reviews is to develop a better understanding of benefits processing and the impact of employment status changes on benefits eligibility. Reference materials are currently being developed to assist the Administrative Officers.

In October the Benefits Office held two retirement planning seminars for 150 individuals and their guests. One session was held on Campus, the other at Lincoln Laboratory. We had intended to hold another seminar in the spring, but could not because of staffing and workload issues.

We completed the consolidation and reorganization of all of the paper records of every employee. This now enables us to access an individual's complete benefits history and file for research and reference, saving considerable time and duplication of work.

We are unable to report any progress in the area of pension calculations. We are still struggling to deal with data problems in the pension accounting system and the fact that the monthly valuation of the plan accounts is still averaging five to seven months behind. We rely on the maintenance of these two areas by the Benefits Accounting Office.

DEBORAH KELLEY

FACULTY AND STAFF INFORMATION SERVICES

Faculty and Staff Information Services has the responsibility to acquire, maintain, and provide employment information about faculty, staff, and other persons affiliated with MIT and to ensure the currency, privacy and accuracy of this information.

The office processed more than 14,000 appointments and changes. In addition, the office continued its role in the processing of salary reviews, in the servicing of the many data requests received from within the Personnel Office and the MIT community, in responding to external employment verification requests, and in the production of the staff telephone directory.

The Records Staff continued to seek ways to improve the daily processing of information and have successfully automated the tracking of appointment forms and actions, and written verification requests.

In the systems and programming area, there continues to be a demand for modifications and reports. Approximately 450 programs are maintained in the office, representing salary reviews, survey data, labor relations statistics, reconciliation reports, and departmental information listings and labels.

There have been two administrative staff changes in the office. Kathleen Flynn, Systems Program Coordinator, has been promoted to the position of Benefits System and Information Supervisor in the Benefits Office. Sandra Titus was promoted from Technical Assistant, Support Staff to Systems Support Consultant. Ms. Titus will provide assistance in the planning and overall coordination of training and implementation programs associated with the new Personnel system. She will also provide technical support for the current Personnel system.

I am pleased to report that the Administrative Computing Steering Committee has approved the proposal recommending a new Personnel Information system. The need for a new system was based in part upon findings of a study, the goal of which was to determine the Personnel Office's future business information systems strategy. The study examined the Personnel Office from the perspective of both internal systems and procedures, and end users outside of the Personnel Office, and concluded that the staff spent too much time on repetitive, clerical tasks and tedious, paper-intensive procedures. In addition, the study noted the inability of departments to access on-line any of their personnel information or to update this information in a straightforward manner; the inability of anyone but the technical staff to create ad hoc reports of Personnel information; the lack of coordination and sharing of information between Personnel, Payroll, and Benefits Accounting; and an on-line information system that is difficult and expensive to use, and which cannot be maintained effectively.

The result of this study was the recommendation that the Personnel Office purchase a new vendor package Personnel system and convert the existing Personnel data to that system. A vendor search had been undertaken to identify, evaluate, and test appropriate package software. This has resulted in the purchase of Cyborg Systems, Inc. which appears to be the best match with the MIT Personnel Office. We've also purchased a VAX 4000 to support the Cyborg System.

A Project Manager has been contracted to manage the implementation of the new Personnel system.

CLAIRE L. PAULDING

LABOR RELATIONS

The Labor Relations Office is responsible for negotiating and administering collective bargaining agreements with the five bargaining units representing approximately 1,700 MIT employees. Duties also include representing MIT in grievance arbitrations and, in some cases, before administrative agencies.

In July, 1990, this Office successfully concluded a new two-year agreement with the International Union of Plant Protection Employees which represents approximately

80 Security Officers at Lincoln Laboratory. The term of the new agreement is from July 1, 1990 through June 30, 1992 and provides for wage and benefit improvements consistent with agreements negotiated with the other four bargaining units and with MIT's budgetary guidelines.

In May, 1991, we commenced negotiations with both the two bargaining units of the Service Employees' International Union (SEIU) and the Research, Development & Technical Employees' Union (RDTEU) for new agreements to replace agreements expiring June 30, 1991. MIT's collective bargaining agreement with the Campus Police Association (CPA) also expires June 30, 1991 and negotiations are scheduled to start shortly.

The number of grievances filed has increased rather markedly over the prior year, particularly at Lincoln Laboratory. Much of the increase seems attributable to the tightening fiscal situation. The number of arbitrations remains relatively low as many grievances have been compromised to the mutual satisfaction of the parties involved. Just three arbitration awards were received during this time period and in all three instances the Institute's position was upheld. Two cases involved questions of promotion of a less senior, more qualified individual in the Institute's judgement over a more senior employee. The third case, involving a claim by an employee that he was doing the work of a higher classification and therefore should be promoted, was also denied by an arbitrator.

In an effort to resolve several outstanding grievances, we worked out a fairly involved reorganization involving several RDTEU classifications, together with the management of the Office of Laboratory Supplies and the RDTEU.

Michael J. Parr, Assistant Manager of Labor Relations left June 30, 1991 after 23 years of service to the Institute.

ROBERT J. LEWIS

PERSONNEL SERVICES AND EMPLOYMENT

This year, the Personnel Officers found themselves spending additional time counseling employees, particularly those individuals who were attempting to change positions or who sought promotional opportunities in a tighter job market. They continue to provide assistance to supervisors and employees on policy interpretation, conflict resolution, and staffing concerns. A review of layoff information and procedures was completed in order to better assist individuals facing layoff due to department reorganization or loss of funds. Also, workshops and related meetings were held with affected individuals. An improved orientation program for new employees was developed and is being presented by Personnel Officers who have assumed the responsibility for welcoming groups of Support Staff as well as Administrative and Research Staffs.

"Positions Available," a listing of open positions that is usually published as an insert to *Tech Talk* every other week, continues to provide descriptions of all available full and part-time positions. Since its inception in January 1990, the communications page in *"Positions Available"* known as *"The Back Page"* and soon to be entitled *"Employee Perspectives,"* provides the MIT community with information on personnel policies and procedures as well as programs and services. Further efforts to disseminate accurate policy information occur as a result of the *"Questions and*

Answers" forum, which invites employees to participate by submitting questions focusing on worklife issues.

Introduced into the Personnel Office this year was a new electronic keyboard testing software package which administers typing tests to prospective support staff on personal computers. This particular program, called *TapDance*, is self-administered and corrects and scores applicants' typing tests. As more and more applicants have requested typing tests on a computer rather than on a typewriter, this new software package has addressed that need and has been well received by those using it. We continue, however, to offer candidates the option of using the electronic testing workstation or electric typewriter.

In order to provide improved communications between the Institute community and the Personnel Office, voice mail was installed in March to help in that endeavor. It has been favorably received by all concerned.

Employment Activity

As the Massachusetts economy continued its decline, the 1990-91 year brought further changes to MIT's employment picture. Because of tightening budgets and lower turnover of employees, there was a decrease in both the number of positions posted and the number of individuals hired by the Institute. However, the applicant and resume volume has increased.

Changes were made to the interviewing and applicant tracking process as well. Beginning in November 1990, the Personnel Recruiter assumed full responsibility for support staff applicants, interviewing more selectively those candidates who most closely match the requirements of the job openings. In addition, shortened and improved applicant referral forms were sent to the department supervisors which resulted in a quicker response time for applicants and more accurate employment statistics.

During the 1990-1991 fiscal year, 629 vacant positions were posted as compared to 868 last year, a decrease of 38%. Specifically, 322 support staff, 120 administrative staff, 24 academic staff, 122 sponsored research staff, and 41 service staff positions were posted. Personnel Office staff interviewed 1,181 applicants for support staff positions, a 23% decrease over 1989-1990 when 1,448 were interviewed. The decrease was due mainly to the more selective screening process. Since November 1990 when the Personnel Recruiter assumed responsibility for all support staff candidates, approximately 1,250 support staff applications have been received. Of this number, 470 candidates were interviewed and 262 candidates were referred directly to Departments. In addition, 20,343 resumes were processed (primarily for other than Support Staff positions) which resulted in a 47% increase over last year when 13,764 were processed. 445 individuals were hired as new employees as compared to last year when 624 people were hired, a decrease of 40%. Approximately 127 people transferred into other positions within the Institute as compared to 187 last year, a decrease of 47%; and 21 former employees were rehired as compared to 15 last year, an increase of 40%.

SALLY H. HANSEN AND ELIZABETH K. MULCAHY

CHILD CARE OFFICE

This has been a year for major expansion in the Child Care Office's programs, outreach, and visibility within the Institute. The Office was staffed by two three-quarter time administrators, Kathy Simons and Rae (Goodell) Simpson, and one full-time administrative assistant, Jill-Beth Sweeney. A promotion for Rae Simpson and new job descriptions for both administrators have created a structure with two co-administrators and clearer and more extensive areas of responsibility: Simons as Administrator of Child Care Resource and Referral Services, and Simpson as Administrator of Parenting Programs.

Major areas of Office activity for 1991 have included individual counseling, workshops, discussion groups, support groups, family day care provider recruitment and training, and a library of books and materials for parents and staff on areas including options for child care, evaluation of child care, balancing work and family, common problems in child discipline, and child development. In response to Institute administrative requests, a series of informational memoranda was established, in areas including family stress, family work hours, and childhood sexual abuse.

The Office experienced an increase in the diversity and complexity of its counseling contacts from MIT parents. These parents have increasingly reflected the full spectrum of MIT families, including more men, more faculty, more service and support staff, more undergraduates, more single parents, more step-parents, and more racial and ethnic minorities. In response to special requests, new materials were added in a number of areas, including children and war, giftedness, and in-home child care. Attendance at parenting programs increased markedly, and in response, the schedule expanded each semester to include several workshops, three discipline series, and several support groups led by MIT staff and outside guests, often in collaboration with other relevant human service departments at the Institute.

The final report of the Ad Hoc Committee on Family and Work was completed in November, and the Office's responsibilities as staff to the Committee ended. However, several meetings were held during the winter to monitor progress toward the establishment and appointment of a permanent Council on Family and Work. During the winter, in accordance with the goals of one of the Committee's child care recommendations, the Office developed and ran an activity-based training program for the campus family day care network in an effort to improve quality and with the long term goal of increasing supply.

The Office continued to act as a resource to MIT's two child care centers. Lincoln Laboratory Children's Center moved from its temporary quarters in the Energy House at Minuteman Vocational Technical High School to a new, larger facility, constructed by the High School to serve 65 children from infancy through preschool in a variety of full and part-time programs. Technology Children's Center established a scholarship program through fund-raising activities, which this year was able to assist four families with the cost of full and part-time care.

The Child Care Office purchased a personal computer work station for each of the three Office staff, significantly increasing efficiency and productivity.

Local and national recognition for MIT's leadership role in the area of work and family has resulted from conference presentations by Simons and Simpson describing the Child Care Office, and in particular recent developments.

KATHY SIMONS

OFFICE OF COMMUNITY SERVICES

On January 1, 1991, the MIT Quarter Century Club Office was renamed the Office of Community Services, and became a part of the Personnel Department. Prior to January 1, the Quarter Century Club Office reported directly to the Vice President in the Office of the President. The name was changed to more clearly indicate the functions of the Office. Susan L. Kendall was appointed as Administrator of the Office, Diane B. Tavitian continues to serve as Administrative Assistant, and Barbara Y. Gilligan serves as Senior Staff Assistant.

The Office of Community Services continues to handle the Quarter Century Club board meetings and social functions. On August 15, 1990, the Club's Picnic, held in Eastman Court, was attended by close to 1,000 members and guests. 105 members were present for the Silver Club luncheon on October 10, 1990 and the Holiday Party, held in the Sala de Puerto Rico of the Stratton Student Center on December 13, 1990, was also a success. At the Annual Meeting on March 26, 1991, a total of 112 new members were inducted, bringing the Club's membership near 2,300. The Quarter Century Club Travel Program was officially transferred to the Alumni Association as of January 1, 1991. During the period July 1 through December 30, 1990, a total of 10 trips to various worldwide destinations were scheduled. The travel business was slow due to the poor economy (local and national) and the unrest in the Middle East.

The Quarter Century Club was founded in 1950, and reported to the Vice President in the Office of the President from 1978 until the recent change in January. There are currently four Officers and an 11-member Board of Directors. Daniel H. Gould continues to serve as Chairman of the Board.

The Office of Community Services also organizes and administers the Institute's annual United Way drive. Receipts for the 1990 campaign totaled \$312,454, against a goal of \$300,000.

The Institute Retirement Dinner is organized by the Office of Community Services on behalf of the President who hosts the event. June 4, 1991 ceremonies were held in Walker Memorial for 149 retiring employees, their guests, and supervisors of the retirees.

The MIT Activities Committee (MITAC), part of the Office of Community Services, continues to organize recreational and cultural activities for the MIT Community and Lincoln Laboratory. Last year 81 planned events were offered, in addition to daily ticket sales for movie theaters, ongoing exhibits, and discounts to area retailers and restaurants.

The Office of Community Services provides staff support and space to the MIT Cambridge Chapter of the American Association of Retired Persons (AARP) which has approximately 200 members. A 20-member board, including seven officers, meets quarterly. Additionally, they organize eight chapter meetings annually, and sponsor several excursions each year for the membership.

Changes in staffing during this past year in addition to those mentioned at the start of this report include the departure of Ann P. Brazier, Manager, and Nanci A. Drago, Assistant Manager. Ms. Brazier left after the birth of her second child, and Ms. Drago returned to school.

SUSAN L. KENDALL

Public Relations Services

This was a year of transition for MIT and one in which a number of major issues converged to affect the climate of research universities in general. The Public Relations Services were heavily involved in the presidential transition, and in addressing such major issues as Congressional inquiries into the ways universities recover indirect research costs, Justice Department inquiries into the ways we administer financial aid, and allegations concerning integrity in research. It was a year of major challenges to the public perception of the value of the research university, even as it was a time of internal renewal and anticipation accompanying the arrival of a new president.

The various offices in PRS relied on teamwork, imagination, and simple hard work to meet the various challenges of the year. With what may seem a small change in operating procedure, we found that our teamwork, especially, was aided by the installation of electronic mail in offices throughout our department, and increasingly throughout MIT. Breaking news was communicated to senior officers from the News Office via e-mail, the Inaugural Committee kept on top of the myriad details in planning the inaugural events and publications via e-mail, the often pressured atmosphere was leavened by jokes via e-mail, and issues requiring fast consultation among several people was facilitated greatly by this, to us, new form of communication. Thanks go to President Vest for urging wider use of this medium throughout MIT.

The reports that follow give the flavor of the year. I am grateful to the entire staff in Public Relations Services for their extraordinary commitment of time, energy, and imagination to helping MIT be the extraordinary place that it is.

KATHRYN A. WILLMORE

COMMUNICATIONS OFFICE

The Communications Office produces the annual Institute reference publications, including two issues of the MIT Bulletin, the Courses and Degree Programs and the Summer Session Catalogue; Reports to the President; Report of the Treasurer; and the telephone directories for students and for faculty and staff. Additional publications such as the Report of the President and Committees of the Institute are published as *Tech Talk* supplements. The office's ongoing objectives are to refine the format and content of its publications and to bring production cycles in-house and on-line, to the greatest possible extent.

Over the past year, the Communications Office worked closely with the Registrar to ensure greater consistency and clarity in the Bulletin's format and content. The office also assumed complete responsibility for the Summer Session Catalogue by collecting and editing copy; redesigning the format; typesetting pages; and distributing copies of the catalogue.

This year, the Reports to the President and the Report to the Treasurer were designed as a "companion set." No outside services were required to typeset the treasurer's reports; all pages were produced camera-ready in the Comptroller's Accounting Office.

The telephone directories changed dramatically in terms of revised front matter, consistent appearance of listings in both directories, and a reorganized index of offices and programs. Using community feedback as a key planning tool, the office worked with MIT students to design, execute, and evaluate two different surveys. The surveys sampled student and faculty/staff reactions to the changes in the directories. For the most part, users reacted favorably and found that information in the publications was well-organized, accurate, and accessible. Additional comments set the direction for future improvements. As an ongoing effort, the Communications Office worked to clarify privacy guidelines and to protect the copyright of information contained in both directories.

In consultation with Stephen D. Scarano, Assistant to the Vice President for information systems, the office has been developing a "technology model" for future interoffice communications. Elements of the

model which have been implemented to date include a link to the network and e-mail; systems administration and tighter security; and training as an "information provider." One example of increased technical facility was the transfer of dozens of files from the Information Center to the Communications Office in order to produce Committees of the Institute as a *Tech Talk* supplement. This year the process was *entirely* electronic. The two offices also worked with Network Services to enter the committee listings on-line as part of the network's public information service, TechInfo.

Personnel

Following a period of transition in personnel, the current office staff has worked together for nearly one year, developing an efficient and enthusiastic team approach. In addition to the manager, the staff includes Marianne Charny, Senior Office Assistant, and Ruth T. Davis, Editor and Production Manager.

BARRIE GLEASON

OFFICE OF DESIGN SERVICES

The Office of Design Services continues to support the communications efforts of MIT by designing and managing the production of publications for departments and offices throughout the Institute. Among the areas receiving major assistance from the office during the past year were the Corporation, Resource Development, the School of Engineering, the Sloan School of Management, the Medical Department, Conference Services, the Media Lab and the MIT Museum.

Included among special projects and events this year were the publications relating to the Inauguration of President Charles M. Vest; the Johnson Games; the report of the Committee on Family and Work; the Chemical Engineering Graduate Program booklet, brochure and poster; the LIDS Symposium: 50 Years and Beyond; the first Martin Luther King Visiting Scholar Award poster; "A Guide to Facilities for the Handicapped" map; the American Peptide Society Conference publications; Power Electronics Society Conference program, booklet and letterhead; the Media Lab 5th Anniversary book; a poster on "Music from the Media Lab: Collage at Symphony Hall"; the MIT Minority Roster booklet; poster for the Vannevar Bush Symposium, "Remembering the Past and Shaping the Future of American Science Policy;" and a brochure on the Arts at MIT.

Overall, Design Services undertook 276 graphic design and publishing projects in 1990-91.

In the computer area, many projects were designed and produced on our electronic publishing system and coordinated through this office for the first time. Continued development of desktop publishing, including the purchase of several new type fonts, enabled our office to work more efficiently and helped significantly in the design and production of in-house publications. With the addition of new software programs we have been able to streamline office procedures and make design publications more cost-effective.

With more of the MIT community using desktop publishing, efforts began last fall to develop and implement design guidelines and templates for clients wishing to produce on their own. For the first time, the Summer Session Office undertook the task of producing some 80-odd folders in-house, electronically, with the help of a design template generated from our office. Work will continue in this area in the coming year, as our office addresses the issue of implementing a more comprehensive network system which will enable us to work more efficiently with major Institute clients.

Among the pieces which were submitted for selection in design publications, there were several from our office which received design awards: Elizabeth Chimento's work was featured in Print's Regional Design Annual/1991, and Celia Metcalf's work appeared in Communication Arts/1991 and Print Casebooks 9.

Personnel

The staff of Design Services during 1990-91 included Elizabeth Chimento, senior designer, Elizabeth Ferry, production manager, Anne Hubbard, senior designer and Lee McMahon, administrative assistant/production coordinator.

CELIA W. METCALF

INFORMATION CENTER

The Information Center is charged with providing service and information in print, in person, and over the telephone to the MIT community and visitors; assisting the international faculty and staff; and coordinating Institute special events, and conferences.

Public Relations and Information

The Center is a clearinghouse for mail addressed to MIT; maintains the official Institute mailing lists; answers and directs to other offices telephone and office inquiries from the public and MIT community; distributes some 39,000 pamphlets, brochures, guides, and catalogues; and maintains records and publishes a *Tech Talk* supplement describing and listing memberships of faculty and presidential committees. General tours of the Institute are conducted through the Center by MIT student guides who are members of an honor society. The tour guide captain, Christina H. S. Kwon (class of 1992) of the Department of Biology, assumed the role as head guide. Between academic studies, Christina trained and scheduled 39 student guides to conduct tours for 8,674 visitors; of these visitors, over 3,000 were prospective students and 1,310 were international visitors. Assisting during the summer as full-time guides were Gregor M. Andrade (class of 1992) of the Department of Economics and Julie Y. Chang (class of 1993) of the Department of Aeronautics and Astronautics.

In addition, special arrangements were made for 611 international visitors to meet with faculty and staff.

The Information Access Working Group (INFACS) is proceeding to implement the following recommendations from our study: 1) placement of consistent, attractive, highly-visible campus maps at strategic locations around the campus; 2) production of indexed pocket-size maps for visitor use; 3) establishment of additional temporary, portable bulletin boards to avoid poster pollution (although this is to be a temporary bulletin board initiative for a short-term intervention, it will demonstrate the need to develop multi-media options for the distribution of information currently supplied by posters); 4) funding for a special Tech Info Provider Start-up Program for a public electronic information service that will provide information on a range of topics such as campus events, class schedules, job openings, and a wide variety of academic and administrative services; and 5) review of the potential for cable television to mitigate existing overextended paper information. In the coming months, many of us will be working together on a systematic and ongoing process to obtain these goals. The Center is now in the process of producing the indexed map that should be out by the fall of 1991.

Arrangements were made for seven delegates and four greetings to be sent to other universities inaugural ceremonies. This function of the office has efficiently been taken over by Karen M. Tenney, Administrative Assistant to the Chairman of the Corporation, and Elizabeth T. Harding, Director of the Office of Communications in Resource Development.

Special Events

The academic year began with a burst of energy – starting with the dedication of the Harold E. Edgerton House, a graduate student residence; a faculty dinner in honor of Paul E. and Priscilla K. Gray; and the Killian Award Lecture given in this academic year by George H. Buchi, Camille Dreyfus Professor of Chemistry.

The Inauguration of Charles M. Vest on May 10 was the major highlight of the spring, planned by a committee of faculty, staff, and students under the guidance of Professor Claude R. Canizares, Director of the Center for Space Research. The Inaugural Events included the Johnson Games and Inaugural Picnic on May 4, the Inaugural Concert on May 9, and the Inaugural Ceremony, luncheon for delegates and guests, and a reception and celebration for the MIT community on May 10. In addition, numerous symposia have been planned as events of the Inaugural year.

Commencement this year began on Sunday, June 2, with the hooding ceremony for over 300 doctoral recipients in Rockwell Cage, which was filled to capacity with family and friends who came to share in this happy event. Monday, June 3, was a beautiful, clear day for the Commencement Exercises. The guest speaker was Dr. Walter E. Massey, Director of the National Science Foundation. The Academic Procession included the 50-year class, who marched 117 strong. Following the Exercises, the President's Reception for families, friends, guests, and the MIT community was held in the areas surrounding McDermott Court.

International Scholars Office

Passage of the Immigration Act of 1990, the most comprehensive revision to United States immigration law in 66 years, will have a strong impact on scholar services offered by our office. Regulations implementing aspects of this bill of greatest concern to the Institute are being written by the Immigration and Naturalization Service and the Department of Labor, and these regulations will go into effect October 1, 1991. We will respond to the proposed rule making as soon as we have the opportunity in an effort to influence some of the procedures and bring them into line with Institute policy and procedure for employing and appointing internationals.

The good news is that the Act allows 140,000 employment-based immigrants to enter the United States every year, almost triple the current level of 54,000. This will considerably shorten the time that it now takes for a faculty or academic staff member to become a permanent resident. Travel restrictions on scholars have also been eased by the Department of State. On the other hand, the Act dramatically expands the burdens and liabilities on MIT as a petitioner for H-1B Temporary Workers and confers significant new powers and duties on the Department of Labor.

Our office will hold a workshop for administrative and personnel officers on the new procedures and related problems and issues that the Act raises as soon as the regulations implementing the Act are known. At the moment, it is a time of transition and uncertainty for many scholars, and advising them is particularly difficult and time-consuming.

With the wise leadership and encouragement of Stephen D. Scarano, the office now has a totally redesigned computer program and a networked system of Macintosh terminals. A computer bridge now exists between our office and the office of the Associate Provost and Vice President for Research so that their offices and others have access to scholar information. We are deeply grateful for our new system and for the opportunities it presents to enter, manage, interpret, and report scholar data. We plan to produce an annual report within the next few months to inform the Institute of the rich diversity of our scholar population. MIT is a profoundly international place with almost 1,800 scholars from 74 countries. We are looking ahead to a time when our computers might network with the Personnel Office mainframe to monitor visa information and the presence on campus of scholars not registered in our office. This is an exciting challenge.

Conference Services

The Conference Services Office manages the logistical arrangements of conferences and meetings that are sponsored by MIT faculty and staff ranging in size from 10 to 1,500. This past year, the Office coordinated 22 such events, which brought more than 7,500 visitors from all over the world to campus, including the Annual Congress of the Cognitive Science Society; the International Conference on Electrical Machines, the Bristol-Myers/Squibb Symposium on "Nuclear Processes and Oncogenes" hosted by MIT's Center for Cancer Research, the Annual Whitehead Institute Symposium, the Twelfth American Peptide Symposium, and the Power Electronics Specialists Conference.

The office also handled the arrangements for more than 100 recruitment presentations by companies and other organizations that visit MIT under the auspices of the Office of Career Services and Preprofessional Advising.

Personnel

This report could not end without mention of Lillian H. Whelpley who retires this June after 38 years of loyal service to the Institute. Starting out in the Biology Department and working throughout the years for senior Institute officers, Lillian came to the International Scholars Office as advisor in October of 1980. Throughout these years, Lillian worked tirelessly not only on the heavy workload of immigration problems but in many personal concerns for many members of our international family--meeting them at airports, helping them find housing, entertaining them over holidays, and tutoring scholars, students, and spouses in English. Her integrity, steadfastness, and capacity for hard work have been a valuable asset not only for the office but for MIT and the community. She will not only be missed for all she has contributed as a staff member in this office but as a friend as well. All of us wish her happiness and the best of luck in her retirement.

Catherine C. Cook has joined the International Scholars Office staff as Staff Assistant and is an Alternate Responsible Officer on MIT's Exchange Visitor Program, able to administer routine aspects of J-1 scholar matters effectively and efficiently.

A salute to the entire staff in the Center, which includes the Conference Services Office and the International Scholars Office, who during this past year took on many extra duties and handled them all with style, grace, and good judgment. To each and everyone, the director would like to give recognition and thanks for their sense of service and commitment to the Institute at large. A very special thank you and grateful appreciation to Gayle M. Fitzgerald, Kathleen M. Barrett, and Donald Ferland whose assistance, hard work, and loyalty during the past few months were more than appreciated. The many tasks they performed during the Inauguration and Commencement are too numerous to mention in this report. Also, a thank you to Jean Warren who was present from January through June to assist the director with the Inaugural Events. Jean immediately adapted herself as a member of our small staff. Her sense of spirit, hard work, and fun will be missed.

MARY L. MORRISSEY

NEWS OFFICE

Developments at the national level have been a continuing challenge for the News Office in the past year in its mission to effectively convey and explain MIT's position on issues which are difficult for the press and public to understand in depth. These developments include:

- The National Science Foundation's decision to place its new magnet research facility in Florida, where no substantial research in magnetics has taken place, rather than at MIT's Francis Bitter National Magnet Laboratory, a leader in this field.
- Criticism by a committee of the House of Representatives of the long-established federal practice of allowing research universities to recover a portion of their general overhead costs through federal research contracts.
- An antitrust suit which accused Ivy League colleges and MIT of conspiring to restrain price competition on financial aid by meeting to discuss the financial needs of joint applicants. The Ivies signed a consent decree, but MIT declined a government request to also sign. MIT said it believes its practices do not violate the antitrust laws.

Tech Talk has been a major channel for communicating responses to questions arising out of these developments—none of which has run its course as this report is written. For the MIT community, *Tech*

Talk has been an important source of answers to the questions many employees were being asked by their associates on questions ranging from magnetic technology to financial aid. For the outside community, the News Office has inaugurated a new reprint technique that has enhanced the effectiveness of *Tech Talk* in putting MIT's views in the hands of reporters and others. As of this writing, 12 reprints have been mailed to a broad list of reporters, science writers and columnists covering the issues of research costs, overhead expenses, tuition, financial aid, the antitrust suit and international relationships at MIT.

Largely as a result of most of the developments mentioned above, five of the six issues of *Tech Talk* published between April 24 and May 29 were 12-page papers. We are searching for ways to do more 12-page issues so that we can continue to adequately report on developments like these and offer in addition more articles on other matters that reflect the varying points of view in the community.

The news-making events of the past year included the inauguration of President Charles M. Vest, the addition of modern biology as a science requirement, Professor James H. Williams sitting outside the president's office once a week in April to call attention to the educational needs of minority students, the address by the Rev. Jesse Jackson on the eve of the Gulf War arranged by the MIT Initiative for Peace in the Middle East, and the revelation that 78 students in a computer programming course were referred to the Committee on Discipline on charges of possible academic dishonesty.

Tech Talk continued its long history as the community's newspaper, providing services ranging from free classified ads and the Institute's only weekly calendar of events to reporting on a variety of issues from appointments to demonstrations. A new feature is a question-and-answer-format interview with a newsworthy MIT figure. Two other new activities merit mention. One is a computer index of articles from *Tech Talk* that now covers 1990 and 1991. The other is the distribution of a daily clippings package to key academic and administrative officials. The clippings, from daily and weekly newspapers and magazines, relate directly to MIT or to a subject likely to be of interest to the recipients.

The News Office also continued to function as the Institute entry point for questions from the press and the public on matters ranging from cold fusion to global warming. We also are involved in documenting MIT's outreach to elementary and secondary schools in a growing effort to raise science literacy. The News Office published its second guide to MIT Educational Outreach Programs and provided input to the K-12 Committee's report on possible Institute initiatives in this area.

Personnel

The News Office support staff for the past year included Cynthia Consentino, receptionist; Lisa Damtoft, senior staff assistant; Myles Crowley, administrative assistant to the director. Their collective enthusiasm, creativity and enterprise has made a major contribution to the mission of this office and to MIT.

A salute as well to the administrative staff working with Director Kenneth D. Campbell and Associate Director Robert C. Di Iorio: Charles H. Ball, senior assistant director; Naomi F. Chase, assistant director/public relations; Donna M. Coveney, assistant director/photojournalist; Eugene L. Mallove, assistant director/chief science writer; Joanne Miller, assistant director/editor-*Tech Talk*; Elizabeth A. Thomson, assistant editor-*Tech Talk*. All have made important contributions.

Just as the year was ending, two members of our team made it known that their departure was imminent. Gene Mallove, who has written several books, plans to pursue private writing and research projects while continuing to be a lecturer in MIT's Humanities Department where he teaches science writing. Cynthia Consentino, a sculptor, is headed for graduate study in California.

KENNETH D. CAMPBELL

Office of the Secretary of the Corporation

This report summarizes the activities and the changes in membership over the past year of the Institute's governing body. The Secretary of the Corporation serves as the Corporation's Recording Officer and as joint signatory with the President in the awarding of the academic degrees of the Institute. The Office of the Secretary of the Corporation is responsible primarily for the four quarterly meetings of the board, the Visiting Committee meetings, and procedures associated with members joining or retiring from the trustee body. It also stands ready, as the need arises, to assist individual Corporation members in the execution of their trustee responsibilities and to support building dedications and other special MIT events.

CORPORATION MEMBERSHIP

Completion of Service

On June 30, 1991, the following members completed their designated terms of service: E. Milton Bevington '49; Ernest U. Buckman '46; Joe F. Moore '52; and Sarah A. L. Tabler '85.

Elections to Term Memberships

The following nine members were elected to the Corporation for five-year terms beginning July 1, 1991: William R. Brody '65; Alexander W. Dreyfoos, Jr. '54; Michael M. Koerner '49; Claudine B. Malone; Christian J. Matthew '43; DuWayne J. Peterson, Jr. '55; Morris Tanenbaum; Reginald D. Tucker '88; and William J. Weisz '48. (Messrs. Dreyfoos, Koerner, Matthew, Peterson, and Tanenbaum have each served a previous five-year term. Mr. Matthew also served during 1990-91 as an *ex officio* member of the Corporation in the position of Alumni Association President. Mr. Weisz has served two previous five-year terms, from 1975 to 1985.)

Election to Life Membership

Charles H. Spaulding '51 was elected to Life Membership, effective July 1, 1991.

Ex Officio Members

In the opening days of the new calendar year 1991, the Honorable Michael S. Dukakis completed two consecutive four-year terms as Governor of the Commonwealth of Massachusetts during which he served as an *ex officio* member of the MIT Corporation in accordance with the provisions of the Charter of the Institute. His successor, the Honorable William F. Weld, currently serves as an *ex officio* member of the MIT Corporation.

On June 30, 1991, Christian J. Matthew '43 completed his term of service as President of the Alumni Association and was succeeded by Peter M. Saint Germain '48.

Transfer to Emeritus Status

At the June 3 meeting of the Corporation, the Chairman noted that on May 19, 1991, Dr. Ralph Landau '41 reached the age of 75, and, in accordance with Section 5.1 of the Bylaws, was therefore transferred to the status of Life Member Emeritus. Dr. Gray paid tribute to Dr. Landau for his exemplary service to the Institute and to the Corporation and welcomed him to the distinguished rank of Life Member Emeritus. To mark this special occasion, Dr. Landau was presented with an MIT wristwatch engraved with his name and the years of his service as a Life Member.

Deaths

At the October 5 meeting of the Corporation, the Secretary presented memorial resolutions honoring Life Member Emeritus Kenneth J. Germeshausen '31, who died on August 16, 1990.

CORPORATION COMMITTEES

Executive Committee

This committee is chaired by the President and includes the Chair of the Corporation and the Treasurer, *ex officio*, and seven elected members. In 1990-91 the elected members were W. Gerald Austen,

Samuel W. Bodman, Edward E. David, Jr., Joseph G. Gavin, Jr., Shirley A. Jackson, Norman B. Leventhal, and Mary Frances Wagley. I have served as Secretary of the committee since 1971.

In 1990-91 the Executive Committee held 10 regular monthly meetings, and 1 special teleconference meeting in October.

Mr. Gavin and Dr. Jackson will complete their terms of service this summer. They will be succeeded by Messrs. Raymond S. Stata and Morris Tanenbaum.

Corporation Development Committee

As in the past, it is anticipated that the activities of this committee will be covered in the annual report of the Vice President and Treasurer.

Investment Committee

The Investment Committee held four regularly scheduled meetings during the 1990-91 fiscal year under the chairmanship of Breene M. Kerr. Serving with Mr. Kerr this year were Frank T. Cary, Norman B. Leventhal, Jerry McAfee, Robert A. Muh, DuWayne J. Peterson, Jr., and John S. Reed. Mr. Cary and Dr. McAfee completed their terms on June 30, 1991. They will be succeeded by Michael M. Koerner, who will serve a five-year term on this committee, and Richard P. Simmons, who will serve a two-year term. Allan S. Bufferd will continue as Secretary of the committee. Both the Chairman of the Corporation and the Treasurer serve as *ex officio* members.

The Wellington Management Company of Boston has continued as investment manager and advisor for publicly traded securities, both domestic and international. In addition, the program for domestic and international alternative investments to publicly traded securities was continued. These alternative investments, including venture capital and management buyouts, are typically managed by several investment managers through pooled investment funds.

Membership Committee

This committee is chaired by the Chair of the Corporation, who also appoints its members. This year those serving with Dr. Gray were Angus N. MacDonald, Carl M. Mueller, Rita A. O'Brien, David S. Saxon, and Morris Tanenbaum. Dr. Saxon completed his term on June 30, 1991, and was succeeded by Edward O. Vetter. The President serves as an *ex officio* member.

The Membership Committee met three times during the academic year, in October, December, and March, for substantive discussions of membership matters. In addition, in January, 1991, Dr. Gray sent a letter to every member of the Corporation asking for suggestions and recommendations for Corporation and committee memberships. Many helpful replies were received, and these comments will be of great assistance to the Membership Committee in its deliberations in the coming academic year.

Elections to membership on the Corporation are recorded earlier in this report, and changes in committee memberships will be recorded in the rosters of Standing and Visiting Committees presented to the Corporation for approval at the Annual Meeting.

Screening Committee

The Corporation Screening Committee to nominate recent graduates to membership on the Corporation was chaired again this year by Sarah A. L. Tabler. The other members of the committee were George P. Gardner, Jennifer L. Lund, Megan J. Smith, and Robin M. Wagner. The committee met a number of times during the 1990-91 academic year. There was an open meeting with students in November, 1990, and four committee teleconferences in January and February. From the 77 nominations received, 6 finalists were selected for the ballot. The ballot was then sent to alumni who had received degrees in 1989 and 1990 and to candidates for degrees in 1991. As reported above, Reginald D. Tucker was the winner.

Auditing Committee

The Auditing Committee was chaired this year by Louis W. Cabot and included Jennifer L. Lund, Harold J. Muckley, DuWayne J. Peterson, Jr., and Charles H. Spaulding as members. There were two meetings, one on October 4, 1990, and one on February 28, 1991. Representatives of the independent public accountants, Coopers & Lybrand, as well as appropriate members of the administration of the Institute, joined the Auditing Committee members at each meeting.

The Financial Statement for the Year Ended June 30, 1990, was the focus of the committee at the fall meeting. At the spring meeting, Mr. Peterson acted as Chair *pro tem* in Mr. Cabot's absence. This meeting was devoted to a summary of the activities of MIT's Internal Audit Division and a review of Coopers & Lybrand's audit plan for the year ending June 30, 1991.

Advisory Committee on Shareholder Responsibility

The Advisory Committee on Shareholder Responsibility (ACSR) met twice this year in the spring and additionally conducted two telephone polls to review 77 shareholder proposals on the proxies of 41 public corporations whose stock is held by MIT.

D. Reid Weedon, Jr., continued as Chair, with Vice President and Treasurer Glenn P. Strehle serving as an *ex officio* member. Elizabeth T. Harding assumed the responsibilities of Secretary, succeeding Walter L. Milne, to provide the committee with staff assistance.

Corporation Joint Advisory Committee on Institute-Wide Affairs

The Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC) held six meetings during 1990-91. Emily V. Wade again chaired the committee. Other Corporation members serving on the committee included Edward H. Linde, Jennifer L. Lund, Christian J. Matthew (*ex officio*), Sarah A. L. Tabler, and Harris Weinstein. Mrs. Wade presented an oral report to the Corporation at its March meeting, and later in the spring a written report was sent to the full board.

CJAC's discussions focused primarily on communication between various constituencies of MIT, on the governance of MIT, and on MIT's reaction to the problems in South Africa.

As an outgrowth of the discussions on the need for better communication, Ms. Lund wrote "A Layman's Guide to the Corporation" (to be published in *The Tech* in the fall of 1991).

After much discussion about student participation on committees such as the presidential search committee and committees assisting in the selection of deans, CJAC passed a vote (thirteen affirmative, two negative) to report the following:

CJAC members feel that the administration of MIT should develop a formal mechanism whereby students would be routinely included in important decisions such as presidential searches, pertinent selection processes, and structural and curriculum changes.

Following a case-study presentation by Professor Willard R. Johnson on issues related to sanctions, divestment, and educational relations with South Africa, CJAC also reported:

With one abstention CJAC is in agreement to support the continuation of U.S. national policy of sanctions against South Africa. The committee has considered several aspects of the South African question, including possible educational initiatives, divestment, and the role of U.S. banks in the South African economy. There is strong consensus that MIT should continue and expand its efforts in the area of educational initiatives -- this being MIT's primary mission. There is a wide range of opinion on the question concerning divestment and the role of financial institutions; this disparity of opinion among committee members may reflect the differences in views of the larger MIT community. CJAC believes that

an assessment of the community's views should be taken into account in any related discussions or decision-making processes.

CJAC expresses to the Corporation that there exists among committee members a strong interest in these issues. CJAC believes that the Corporation should expeditiously review the Institute's investment policy including the conditions presently acceptable under the Statement of Principles as well as conditions that might be more appropriate -- perhaps more stringent criteria -- under changing conditions.

CJAC believes that the Institute should develop the means to monitor, evaluate, and communicate broadly MIT's commitment to assisting with the problems of South Africa (e.g., publicize scholarships, fellowships, and available faculty funds for educational programs).

Dr. Ingrid Fritsch-Faules was invited to attend several CJAC meetings as a postdoctoral representative. At CJAC's last meeting in April, Dr. Fritsch-Faules presented a report on concerns of postdoctoral fellows at MIT. Agenda items for the coming academic year were also discussed.

In the fall CJAC members were invited to attend an annual dinner with the Corporation Screening Committee and student leaders, followed by an open meeting to discuss the functions of MIT trustees and the process by which recent graduates may become candidates for membership on the Corporation.

Corporation Visiting Committees

During the academic year 1990-91 twelve Corporation visiting committees held meetings:

Fall 1990	Visiting Committee	Chair
September 24-25	Biology	W. Gerald Austen
October 23-24	Humanities	Mary Frances Wagley
October 30-31	Libraries	Robert A. Muh
November 8	Aeronautics and Astronautics	Joseph G. Gavin, Jr.
November 13-14	Chemistry	Jerry McAfee
December 5-6	Architecture and Planning	Alexander W. Dreyfoos, Jr.
Spring 1991	Visiting Committee	Chair
March 4-5	Chemical Engineering	Samuel W. Bodman
March 14-15	Student Affairs	DuWayne J. Peterson, Jr.
April 3-4	Electrical Engineering and Computer Science	Raymond S. Stata
April 18-19	Political Science	Angus N. MacDonald
April 23-24	Economics	John K. Castle
May 1-2	Ocean Engineering	George P. Gardner

The Aeronautics and Astronautics Visiting Committee convened for a one-day special meeting (as previously agreed to at the conclusion of its biennial meeting in March, 1990) to provide assistance to the department in articulating the conclusions and resulting new directions of the planning group's Strategic Plan. Mr. Gavin, Chair of the Committee, gave an oral report on this special meeting at the Corporation meeting in December, 1990; however, there was no written report. Joseph S. Dunning, a dedicated member of the committee for fourteen years, died on January 30, 1991.

D. Reid Weedon, Jr., in Mr. Peterson's absence, served as Acting Chair at the Student Affairs Visiting Committee meeting. At that same meeting Mr. Weedon was honored for his decades of prior service as Committee Chair.

In response to recommendations from the Humanities Visiting Committee in 1988 and again in 1990, the Executive Committee approved the establishment of a new Corporation visiting committee for Music and Theater Arts.

All pending oral and written reports were completed for committees which had met in the academic year 1989-90. Oral and written reports were completed for committees which met in 1990-91 with the exception of three oral reports (Economics, Electrical Engineering and Computer Science, and Political Science) and four written reports (Economics, Political Science, Ocean Engineering, and Student Affairs).

In 1990-91, 347 persons occupied 406 slots (121 filled by Corporation members, 137 filled by alumni nominees, and 148 by presidential nominees) on the Institute's 24 Corporation visiting committees. Membership included 21 percent women and 8 percent underrepresented minorities. Employment of members included 56 percent affiliated with corporations; 33 percent with academia; 5 percent with government; 4 percent with foundations; and 2 percent with other. Two members resigned during the year: E. P. Blanchard, Jr. (Chemical Engineering) and J. R. Street (Sponsored Research).

Membership of the Institute's 25 Corporation visiting committees (including Music and Theater Arts) was replenished for the academic year 1991-92: 59 members completed their service on June 30, 1991; 135 members were asked to serve an additional term; and 85 new nominees were invited to serve.

MEETINGS OF THE CORPORATION

Orientation Program

On October 4, 1990, the day preceding the Annual Meeting, an orientation program was held for new members of the Corporation. The program began with a luncheon at the President's House and an afternoon of presentations by the officers of the Corporation on the structure of the trustee body and an overview of the Institute by the President. Following the presentations and discussion, the new members were taken on a tour of the campus. At the end of the tour, the new members were joined by the members of the Executive and the Membership Committees for a dinner at the Faculty Club. As in the past, spouses of new members were invited to all the orientation events.

Annual Meeting

At the Annual Meeting on October 5, 1990, the agenda included the annual reports of the President and the Treasurer. The President's Report was of special significance this year since it was Dr. Paul E. Gray's tenth and last report as President of the Institute and included not only a summary of the highlights of the past year but also some reflections on his decade as President. There were many expressions of affection and admiration for Paul and Priscilla Gray from the members of the Corporation, who also expressed their pleasure in Dr. Gray's continuing role at MIT as Chairman of the Corporation.

It was also Dr. David S. Saxon's last meeting as Chairman of the Corporation, and the members warmly expressed their appreciation for the many contributions that David and Shirley Saxon had made to the Institute during David's seven years as Chairman of the Corporation. Citing the precedent set by Dr. Vannevar Bush in 1971 when he resigned the Honorary Chairmanship and nominated James R. Killian, Jr., as his successor, Howard W. Johnson formally resigned his position as Honorary Chairman and proposed that he be succeeded by Dr. Saxon. His proposal was passed, and Dr. Saxon was named Honorary Chairman, effective October 15, 1990. On behalf of the members, Samuel W. Bodman thanked Mr. Johnson for his characteristically thoughtful gesture and commended him for his many years of distinguished service to the Institute.

In one of his last acts as Chairman, Dr. Saxon, on recommendation of the Executive Committee, proposed a vote appointing Carl M. Mueller as Honorary Lecturer "in recognition of his trustee leadership and unparalleled contributions to the Massachusetts Institute of Technology." The motion was enthusiastically approved by the members of the Corporation, and Mr. Mueller became MIT's fourth Honorary Lecturer, joining Cecil Green, Eugene McDermott, and Winston Churchill in this distinguished rank.

Although Dr. Charles M. Vest did not officially assume the presidency until October 15, at the October 5 meeting he was asked for some early reflections based on his three months of residence in Cambridge.

In his brief informal comments the President-elect delighted the members with his keen observations and his spontaneous eloquence.

This was indeed a memorable meeting!

December Meeting

At the meeting of December 7, 1990, many members of the Corporation participated in a substantive discussion of MIT policy as it relates to companies doing business in South Africa. Although varying points of view were expressed, there was agreement that the most recent communication from the Coalition Against Apartheid (CAA), being more civil and more moderate in tone than previous missives, was encouraging in terms of possible future exchanges. Dr. Gray said he would ask the Investment Committee, the Advisory Committee on Shareholder Responsibility, and the Executive Committee to re-examine the issues and consider the alternatives, noting that the Executive Committee has continuing responsibility for action on this matter.

At this meeting there was also a discussion of the Institute's relationship with the Whitehead Institute. The affiliation agreement, signed in 1982 and now nearing its tenth anniversary, has resulted in very satisfactory and congenial arrangements between the two institutions. Further, the association has made it possible to expand greatly the scale of what is undertaken in the Department of Biology. The Provost reported that Dr. Gerald R. Fink, who succeeded Dr. David Baltimore as Director of Whitehead, shares with the MIT Provost an optimistic view of the future relationship between the two institutions.

Following the business session, members of the Faculty Council and their spouses were guests of the Corporation at a luncheon at the Faculty Club. There was no formal speaking program in order to allow maximum opportunity for conversation among the members of the Corporation and their Faculty guests.

March Meeting

At the invitation of President Vest, Professors Henry W. Kendall and Jerome I. Friedman of the Department of Physics joined the meeting of March 1, 1991, to talk about the discoveries for which they, along with their Stanford colleague, Richard E. Taylor, had been awarded the 1990 Nobel Prize for Physics. The Corporation members followed the presentations with much interest and expressed their appreciation for the achievements of these distinguished laureates with sustained applause.

Also present at the meeting at President Vest's invitation was Dr. Joel Moses, recently named Dean of Engineering, who talked briefly about his view of the challenges and opportunities of this important MIT post.

In his quarterly report, President Vest reflected on a number of major issues that the Institute is facing at this time. These included the government's review of university procedures related to the recovery of indirect costs for research. This review, which began as an inquiry at Stanford University, had received a lot of publicity because of alleged irregularities found in accounting and reporting practices at Stanford. A number of Corporation members participated in the discussion following the President's comments. It was noted that the unfortunate publicity that often results from inaccurate reporting of investigations of this kind helps to erode public support for science. To combat this, Corporation members urged MIT to take a leadership position in efforts to educate the public about the importance of university research on science and technology.

At the March 1 meeting it was announced that the Cabot Corporation was making a gift to MIT of \$100,000 to establish an MIT Trustees Award to be conferred on an individual or team of MIT students, faculty, or staff, who had demonstrated uncommon leadership in the fulfillment of MIT's mission in education, research, and public service. The award, to be proposed from time to time by the President of MIT and voted by the Executive Committee of MIT, was established in recognition of the distinguished service of three MIT alumni and trustees who served as members of the Cabot Corporation for a combined total of 51 years: Paul E. Gray, Carl M. Mueller, and Edward O. Vetter.

Following luncheon, a number of Corporation members attended a meeting organized by members of the Coalition Against Apartheid (CAA) for informal discussion of issues related to South Africa.

Commencement Meeting

The Corporation held a breakfast meeting prior to the Commencement exercises on Monday, June 3, 1991. As is customary at the Commencement meeting of the Corporation, new Term and Life Members were elected (see above) and Commencement degrees were voted. Professor Henry D. Jacoby, completing a two-year term as Chair of the Faculty, expressed his pleasure in having had the opportunity to work with the Corporation. He also expressed his strong support for the effective partnership of the Faculty and the Corporation, commenting on how this partnership works to MIT's advantage, especially in such matters as the recent presidential search.

In his quarterly report the President discussed further the situation with regard to the recovery of indirect costs of research. Following his formal remarks, he responded to a number of questions from the members, who continue to follow this situation with close attention. The President also reported on the Justice Department's complaint against MIT and the eight Ivy League schools, but in this instance limited his comments since this is a matter currently in litigation.

At the graduation exercises following the business meeting, 38 Corporation members marched in the academic procession. These included Dr. Gray and Dr. Vest, who marched in the Guest of Honor Division; the Honorary Chairman, Dr. Saxon, who marched with the 50-year Class along with his 1941 classmates, Messrs. Gavin, Mueller, Weedon, and Wyle; Mr. Matthew, who, as President of the Alumni Association, served as Chief Marshal; and Mr. Buckman, who was Marshal of the Corporation.

Following the graduation exercises, Dr. and Mrs. Gray held the traditional Chairman's luncheon in the Sky Room at 100 Memorial Drive. The luncheon, which always provides welcome relaxation after a long morning, had a full attendance including Dr. Walter E. Massey, Director of the National Science Foundation and this year's MIT Commencement speaker, and President Emeritus and Mrs. Stratton.

SPECIAL EVENTS**Edgerton House Dedication**

On Friday, December 7, 1990, following the quarterly meeting of the Corporation, the new graduate residence at 143 Albany Street, Cambridge, was formally dedicated. On the recommendation of the Executive Committee, the Corporation had approved the naming of this fine new facility in honor of the late Professor Harold E. Edgerton '27 "in recognition of his extraordinary compassion, generosity, and enthusiasm as a teacher of MIT students for nearly sixty years." Dr. Gray presided at the ceremonies, which many Corporation members attended. The speakers included President Vest; Arthur C. Smith, the Acting Dean for Student Affairs; Michael D. Grossberg, the President of the Graduate Student Council; and Mrs. Edgerton. Many guests took tours of the new residence and remained for the bountiful reception, which attracted many of the house residents.

Inauguration

On Friday, May 10, 1991, Charles M. Vest was inaugurated as the 15th president of MIT in a colorful ceremony in Killian Court. Dr. Vest, who took office on October 15, 1990, was formally invested by MIT's 14th president, Paul E. Gray, now Chairman of the Corporation. MIT's 12th and 13th presidents, Howard W. Johnson and Jerome B. Wiesner, participated in a full day of activities which began when Carl M. Mueller, Life Member of the Corporation and chair of the presidential search committee, led the academic procession, which included many Corporation members, into Killian Court. Among the institutional delegates were a number of university presidents including Derek C. Bok of Harvard University; Benno C. Schmidt of Yale University; James J. Duderstadt of the University of Michigan, where Dr. Vest had served as Provost; and Frank H. T. Rhodes of Cornell University, who spoke at the inauguration ceremony. The newly installed President delivered his Inaugural Address, copies of which were later sent to all members of the Corporation.

Following the ceremony, there was a reception for the MIT community on the Kresge Oval and a luncheon in Rockwell Cage for more than 1600 delegates and guests. At the luncheon formal greetings were offered by a number of the guests including Christian J. Matthew, President of the Alumni

Association; Massachusetts Governor William F. Weld, who serves as an *ex officio* member of the Corporation; and U. S. Senator from Massachusetts, Edward M. Kennedy.

Many members of the MIT community participated in one or more of the events on Inauguration Day. In addition, during the week of May 4-11, there were a number of special events associated with the inauguration of Dr. Vest which drew together members from many different branches of the MIT family. The opening event on Saturday, May 4, was the celebration of the Johnson Games, which this year attracted several thousand Faculty, students, and staff, who, on the fields adjacent to the Johnson Athletics Center, joined in friendly competition from early morning to mid-afternoon and tested their skills in a variety of games. The games were followed by an inaugural picnic on the Kresge Oval, where rival teams feasted side by side and regaled each other with tales of the morning's feats. The day's events concluded with the serving of a massive cake with colorful letters welcoming President and Mrs. Vest to the MIT community.

A week later more than 300 people ran in the annual MIT Community Service Road Race, which this year generated additional interest and excitement as one of the inaugural week events.

With the events noted above, including an extraordinary series of three evening concerts in Kresge Auditorium during inauguration week, every member of the MIT community who wished to take part in one or more of the activities associated with the inauguration of MIT's 15th president was able to do so. Institute-wide participation was one of the goals emphasized by President Vest when he took office in October, 1990, and was consulted by the inauguration planners. This goal was very satisfactorily achieved, and those of us fortunate enough to be at MIT during the opening months of President Vest's administration will long remember the many joyful and colorful events that celebrated the inauguration of his presidency. Professor Claude R. Canizares, Chair of the Inauguration Committee, and many dedicated staff members gave their talent and time to making this occasion a memorable MIT community event.

Celebration of the Ninetieth Birthday of President Emeritus Stratton

May 18, 1991, was the 90th birthday of President Emeritus Julius A. Stratton, and on the previous day, May 17, he was honored at a party that was arranged by the students and staff of the Julius Adams Stratton Building, which this year celebrated its 25th anniversary. More than three hundred friends and admirers from the ranks of Faculty, students, and staff attended the gala affair which was held in the Catherine Stratton Lounge of the Stratton Building and featured the traditional birthday cake and Dr. Stratton's favorite ice cream, maple walnut. Also attending were many members of the Stratton family including Dr. and Mrs. Stratton's three daughters and their granddaughter. Mrs. Rebecca M. Vest presided over the program with characteristic warmth and graciousness. President Emeritus and Former Chairman of the Corporation Howard W. Johnson brought greetings from Dr. Gray, Dr. Vest, Dr. Wiesner, Dr. Saxon, and himself to "MIT's beloved elder statesman" along with "the affectionate best wishes of the entire MIT community."

Meeting of Board Secretaries

On Thursday and Friday, June 27 and 28, 1991, MIT was the host institution for a meeting of board secretaries. Institutions participating in the meeting included Case Western Reserve, Columbia University, Dartmouth College, Emory University, Johns Hopkins University, University of Michigan, Northwestern University, University of Pennsylvania, Rensselaer Polytechnic Institute, Washington University of St. Louis, and Wellesley College. Discussions were focused on the topic of *Changing Expectations: Leadership, Membership, and Public Trust*. At the introductory session on the afternoon of June 27, the participants described their trustee boards and outlined the responsibilities of the board secretary at their individual institutions. Following the opening session, the visitors took a tour of the MIT campus and then reconvened for dinner at the Faculty Club. At dinner there was a lively discussion of the changing climate in universities today, particularly with respect to relationships with the federal government. Discussion was continued the next morning when President Vest joined the group for breakfast to talk about this and other issues confronting higher education in the final decade of the twentieth century. He expressed the opinion that institutions of higher learning must work together to solve these problems of national significance, a point of view shared by a number of the participants.

The discussion preceding the closing luncheon on June 28 was wide-ranging and included a description by each of the participants of board membership procedures at his or her institution. With so many participants and so many topics of interest, it was recommended that next year's meeting, which will take place at the University of Pennsylvania, be a day and a half in length.

The MIT Secretary and Associate Secretary enjoyed and were enriched by the visit of their colleagues in trustee administration from peer institutions.

CONSTANTINE B. SIMONIDES

4

VICE PRESIDENT FOR FINANCIAL OPERATIONS

In Fiscal 1991, MIT essentially achieved a balanced budget. While the Institute used \$9.0 million of unrestricted gifts, grants, and bequests and \$0.3 million of current funds to balance the Fiscal 1991 operating budget, no funds functioning as endowment or reserve balances were used to fund the small deficit.

Other measures of financial strength are also favorable. Over the past five years the market value of all the investments increased by 51% to a new high of \$1,774 million. The investment income distributed for spending from endowment funds increased by 11% to \$68.5 million.

Total borrowings decreased by 8% and the Institute's public debt continues to be rated at AAA.

There is continuing pressure on the operating budget, however, from resource constraints as MIT attempts to maintain its academic excellence and pursue new opportunities. It is difficult to meet all objectives of reasonable growth in tuition and self-help levels, competitive salaries for faculty and staff, and need-blind admissions. Despite our best efforts to control costs, there are both unexpected and necessary Institute-related events which require greater expenditures. Recent examples include: legal fees, health care costs, utility costs, and undergraduate financial aid. As well, the budget forecast contains many assumptions that add to the risk of achieving a balance between current expenses and revenues.

Among these financial pressures, there are two major financial issues discussed below. The first issue is the possibility of reduced growth in research volume both on-campus and at Lincoln Laboratory and the prospects of a decline in indirect cost recovery as the result of continuing governmental pressure to reduce this recovery. The second issue is the demand for increasing levels of unrestricted funds to continue MIT's policy of need-blind undergraduate admission.

Research Funding and Indirect Cost Recovery

Research funding levels both on and off-campus are expected to be limited in growth over the next few years. There are a number of reasons for this reduced funding, including reduction and redirection of the Defense Department budget, general government budget constraints, increased research funding to other universities, in some cases through congressional earmarking, and the effects of the economy on industrial and foundation sponsorship of basic research.

Additionally, the political climate for reimbursement of expenses for indirect costs could significantly alter our past practices of recovery of sponsor's (primarily the government) "fair share" of indirect cost. These changes are evident in recent congressional attention to university reimbursement for these expenses at all research universities, and we have experienced it at MIT in recent audit activity by government audit agencies. Many practices and agreements entered into jointly between MIT and the government are now being questioned with suggestions for unilateral changes. It is difficult to project the extent of financial impact with any certainty at this time until we determine the extent of the changes being recommended by these audit agencies and how our government contracting authority will respond to these recommendations and our responses.

The Office of Management and Budget (OMB) has issued two modifications to Circular A-21 which governs direct and indirect cost reimbursement for universities. In May, they issued an amendment on specific items which would no longer be allowable as a recovered expense, such as Alcohol, lobbying, etc. They also set a ceiling on the salary rate for both direct and indirect cost of \$120,000 per annum. An amendment in June established a cap on certain administrative costs at 26% (MIT's rate is between 21-23% depending on interpretation of space cost). We have responded to both amendments, generally supporting the first amendment (except for the salary limitation which we believe is punitive), and objecting to the cap on principle. We have been joined in objections to the cap by most other universities, and to a large extent by Congress. The issue is still to be resolved.

For a number of years MIT has been faced with the problem of providing increased funding from MIT unrestricted funds to supplement other sources of financial aid to continue to admit undergraduate students regardless of financial need. In the mid 1980's, a Task Force on Undergraduate Financial Aid Policy was formed to study this problem. The deliberations continued over a number of years and a comprehensive report was issued that stressed the desire to continue need-blind admission, but suggested a number of measures to attain this goal without dramatically increasing the need for unrestricted funds.

One of the recommendations was the development of a figure of 15% of tuition income as the caution line for the unrestricted supplement from MIT unrestricted funds. While the number was only a guideline, the committee recommended that any significant movement above this number should be considered as a time to review options. The Task Force also recommended the use of a self-help level increase of 2-3% above the tuition increase percentage as a way to remain within this 15% limit. The supplement/tuition ratio has risen to 17% in Fiscal 1991, and projections show that it will rise higher in comparison to projected increases in endowment income for scholarships, and federal and other sources of grants and loans. We need to review our policy in this area and decide an optimum tuition/self-help/endowment income scenario to assure continuance of need-blind admission without a significant increase in unrestricted supplement.

The events of the past year in the area of audit and financial review have necessitated efforts by many members of Financial Operations well beyond their normal responsibilities. These extra efforts are very much appreciated by all members of the MIT community.

At the same time, a number of new programs and systems have been introduced to streamline operations and increase efficiency in financial control and reporting. The reports that follow highlight these and other activities of the last year in the five major areas of Financial Operations.

The reports of each department highlight the major activity that has occurred during the year. While they describe many of the activities, they cannot adequately express the amount of care and effort of Financial Operations staff to ensure that the finances of MIT continue to be effectively managed. I extend my sincere appreciation to all members of Financial Operations for their outstanding efforts.

AFFIRMATIVE ACTION EFFORTS IN FINANCIAL OPERATIONS AREA

Increasing the numbers of women and minorities in career positions continues to be a major goal of the area. Every search plan and appointment to the Administrative staff is reviewed by the five area department heads, with final approval, on their advice and consent, by the Vice President. This procedure has been effective in keeping affirmative action efforts a priority on a weekly basis. This attention has had good results in the hiring and promotion of women and minorities. We must, however, continue these efforts as a major priority of the area.

As of June 30, 1991, the total number of women administrative staff is 99 (43%), while underrepresented minorities are 18 (8%) of the administrative staff of 228. (In 1990, these figures were 90 (42%) and 18 (8%) of 213, respectively.)

Including support and service staff members, the percentage of underrepresented minorities is 47 (11%) of a total staff of 414. (In 1990, the figure was 48 (12%) of 403.)

A statistical analysis of affirmative action results follows for each major area of Financial Operations:

Comptroller

Comptroller's Accounting Office, Lincoln Laboratory Fiscal Office, Audit Division and Property Office

The number of women administrative staff members is 43 (36%) out of a total administrative staff of 118. (In 1990, the figure was 40 (37%) out of a total of 109.)

The number of underrepresented minorities is 19 (9%) out of a total staff of 216. (In 1990, the figure was 18 (9%) out of 205.)

Office of Financial Planning and Management

The number of women administrative staff members is 6 (46%) out of a total administrative staff of 13. (In 1990, the figure was 6 (50%) out of 12.)

The number of underrepresented minorities is 1 (7%) out of a total staff of 14. (In 1990, the figure was 2 (15%) out of 13.)

Office of Purchasing and Stores

The number of women administrative staff members is 8 (31%) out of a total administrative staff of 26. (These figures are identical to the 1990 figures.)

The number of underrepresented minorities is 11 (15%) out of a total staff of 73. (In 1990, the figure was 12 (16%) out of 77.)

Office of Registration and Student Financial Services

The number of women administrative staff members is 34 (74%) out of a total administrative staff of 46. (In 1990, the figure was 27 (66%) out of 41.)

The number of underrepresented minorities is 13 (17.5%) out of a total staff of 74. (In 1990, the figure was 13 (18%) out of 71.)

Office of Sponsored Programs

The number of women administrative staff members is 7 (39%) out of a total administrative staff of 18. (In 1990, the figure was 8 (42%) out of 19.)

The number of underrepresented minorities is 3 (10%) out of a total staff of 30. (In 1990, the figure was 3 (10%) out of 31.)

JAMES J. CULLITON

Office of the Comptroller

Payroll

In August 1990, the project to transfer the Lincoln Laboratory employees to the Campus Payroll System was completed with the conversion of the weekly-paid employees. Since campus and Lincoln Laboratory employees will be subject to the same payroll reporting procedures, this project also required a new time reporting system for the Lincoln Laboratory Payroll Office and an upgrade to the union retroactive payroll system. The VMLIB conversion, a software library management system, was installed to provide greater control of program and system modifications; and a considerable effort was applied to an upgrade of our NATURAL language retrieval system. Significant tax reporting modifications, which are becoming an annual task, were implemented on schedule.

Financial Systems

A major conversion of the General Ledger System to the NATURAL 2 computer language led to the opportunity to make the system more efficient. The result was a reduction of over nine hours in computer run time. This reduction in time has helped us continue to produce accounting statements in a more timely manner. An enhancement to the Accounts Payable System which produces computerized checks on demand has resulted in increased service to the MIT Community. Efforts to complete a more user-friendly and flexible Travel System providing better management tools, and efforts to complete a new billing system providing better control and more management reporting for the Sponsored Research Accounting Office are ongoing. Working in conjunction with State Street Bank and Bank of Boston, the Investment System has been enhanced to automatically reconcile the bank data with Investment Accounting Office data which has reduced tedious manual labor from several days to a few hours.

Benefit Accounting

Retiree increases totaling slightly over \$1 million were paid to 301 Retirement Plan for Staff Members and 1,487 Retirement Plan for Employees members' spouses or beneficiaries and included with their June 1991 benefit checks. The method of tax reporting of annuities and lump sum pension payments was revised. New fields were added to the database to accommodate a new method of passing data to our actuaries for valuation of matured and non-matured accounts and for plan discrimination testing. Pre-1989 benefit accruals were added to the database for those eligible whose accruals ceased earlier under prior plans and for those who were previously prohibited from membership in a pension plan. Adjustments were made to accommodate the moving of Lincoln Laboratory payrolls to the Campus Payroll System. The Tax Deferred Annuity Report was revised and changes were made to the Pension Accounting System to handle prorated market adjustments on variable transfers and return of contributions accounts.

THE PROPERTY OFFICE

The Property Office is responsible for the accounting and asset management of more than 100,000 items of equipment which are both MIT-owned as well as sponsor-owned. During the year, over 11,500 newly acquired items of moveable equipment were identified and tagged. The biennial inventory of items of moveable equipment continued with 75 departments being completed. Two hundred sixteen final inventories were submitted as part of closing out the contracts, grants, and agreements, etc. There were 499 financial reports prepared and submitted to various government agencies. Monthly reconciliation of the accounting records with the property records continued with very positive results. One hundred twenty-six items of excess government equipment with an original acquisition cost of \$75,000 were acquired. One hundred forty items of equipment with an acquisition value of \$67,000 were transferred between MIT departments as part of a reutilization program. Equipment, unneeded or unusable by the MIT Community, was sold for \$456,000 providing funds for replacement equipment. Most of the equipment available for reutilization or sale continued to be displayed at the MIT Equipment Exchange.

Release 2 of the new Property Inventory and Accounting System is being tested prior to use in production.

The Society for Property Administrators, which is administered by the Property Office, conducted a three-day Property Management Conference in San Diego, California, in December 1990. More than 150 attendees from the United States and Canada were present at the conference.

LINCOLN FISCAL OFFICE

In August 1990, the final conversion of the Lincoln Laboratory Payroll System to the Campus Payroll System was successfully completed. In conjunction with this conversion, new time sheets were introduced to the Lincoln Laboratory community in February, 1991 and are working smoothly.

The Lincoln Fiscal Cashier's Office moved into its expanded and modernized quarters in December, 1990 providing a more efficient and pleasant atmosphere for both the Cashier's Office employees and for customers.

The Automated Purchasing System is on-line to two divisions of Lincoln Laboratory with plans being formulated to bring the remaining divisions to a fully automated basis in the fall of 1991.

THE AUDIT DIVISION

The Audit Division continues to service the Institute in accordance with its stated mission of providing reasonable assurance to management that policies are being adhered to as intended, adequate internal controls are being maintained, and assets are properly safeguarded. This is accomplished through reviews of: departments, laboratories, and centers to ascertain whether units are operating according to MIT guidelines and within prescribed contractual and budgetary limitations; administrative systems with focus on the effectiveness of general operating procedures and on automated system controls and data security; and inventories, receivables, and cash (or cash equivalent) to evaluate the controls over and usage of MIT's assets as well as to verify valuations for annual statement presentation.

Accomplishments in the past year include completion of a broad range of reviews encompassing many aspects integral to the financial operations of MIT. Coverage of departments, laboratories, and centers regarding compliance with Institute policies and procedures has been strong. In addition to this effort, field work in many audit areas resulted in significant findings and requests for additional audit services. Operational review efforts increased as planned as well as involvement in new administrative systems development.

Our audit coverage is coordinated with the Institute's Certified Public Accounting firm of Coopers & Lybrand and MIT's federal cognizant audit agency, the Defense Contract Audit Agency (DCAA). The issuance of new federal audit guidelines by the Office of Management and Budget (OMB), *Audits of Institutions of Higher Education and other Non-Profit Organizations* (Circular A-133), formalized the coordination of audit effort among the various entities. The circular establishes audit requirements for non-profits receiving federal funds and calls for an organization-wide audit utilizing a coordinated audit approach involving the Audit Division, DCAA, and Coopers & Lybrand. Under the Fiscal Year 1992 A-133 Audit Plan, Audit Division efforts will not require significant deviation from normal planned audit coverage. Primary A-133 linked audits include continuation of the Departmental Review effort, reviews of selected Institute inventories, several Operational Reviews, and an expanded review of MIT's Program of Self-Governance, a federal initiative to help avoid improper business practices of major federal contractors.

Effort for 1991 was consistent with the long-term strategy implemented in 1990 to allocate audit resources based upon an analysis of the risk involved. The primary focus is currently on Operational Review coverage involving analyses and appraisals of various administrative functions within the Institute and has extended to the evaluation of outside contractors. Our Departmental Review effort continues in earnest with increased attention on the proper use of object codes and identifying costs that are unallowable for government reimbursement according to the anticipated amendment to OMB Circular A-21, *Cost Principles for Educational Institutions*. The Audit Division continues to play an active role throughout the development of data processing applications as well as evaluating the controls within existing administrative systems. Involvement at Lincoln Laboratory will be maintained in accordance with a long-range plan developed in conjunction with Lincoln Laboratory management.

Personnel Changes

The following staff changes occurred within the Comptroller's Office during the past year:

New Appointments

Jean M. Cronin
Property Auditor

Emerson P. Davis
Auditor II

John P. Donahue
Auditor I

David F. Goodwin
Staff Accountant

Shyamal A. Jajodia
Auditor II

Diane R. Monahan
Data Base Manager-Payroll Records

Kathy M. Paquette
Auditor I

Paul L. Smith
Property Auditor

Gretchen S. Sullivan
Auditor I.

Carl P. Whitaker
Senior Staff Accountant

Resignations

Michelle M. Aimone
Technical Writer I

Elizabeth A. Kelley
Senior Staff Accountant

Robert M. Slauzis
Accounting Officer

Stephen H. Zimmerman
Auditor II

Promotional Appointments

Lyle G. Aker
Property Administrator

Veronica R. DuLong
Property Auditor

Alexander J. Kasheta
Property Administrator

Promotions

Debra E. Cobb
Assistant Accounting Officer

Maynard E. Charles
Senior Staff Accountant

Robert M. Damian
Auditor I

Paul J. Enis
Property Manager

Elizabeth A. Greene
Senior Analyst/Programmer

Robert J. Long
Senior Accounting Officer

Clare E. Stanley
Analyst/Programmer III

Scott T. Thornhill
Accounting Officer

Kimball C. Warren
Consultant II

Richard E. Yapple
Analyst/Programmer III

Office of Financial Planning and Management

FISCAL 1991 RESULTS OF OPERATIONS

Total operating expenses for the year were \$1,085.6 million - up 2.1 percent from the previous year. Total operating revenues were up 2.4 percent to \$1,085.2 million leaving a deficit of \$0.3 million. The original projected deficit reported to the Executive Committee in May of 1990 was \$2.7 million. This deficit was revised upward to \$3.4 million as a result of increasing employee benefit costs. The actual deficit of only \$0.3 million resulted from expenses that remained well within budgeted levels and a strong increase of \$3.5 million in unrestricted gifts.

The Institute's operating budget is planned to essentially break even, with small surpluses or deficits occurring each year. In the last decade there have been five surplus years and five deficit years. None of the operating surpluses or deficits have exceeded one percent of total expenses. The Institute expects the essentially break even budget situation to continue in the future.

Surpluses resulting from operations are generally added to funds functioning as endowment or used to acquire or upgrade facilities. Deficits are funded from unrestricted funds availed of but not contained in the budget. The market value of these unrestricted funds is approximately \$120 million. Although the source of the funds is unrestricted, they have been designated for transitional use in years of financial hardship resulting from forces outside of the Institute's control.

It is important to note that small surpluses or deficits in operations do not convey the underlying financial strength of MIT. A better measure of this strength is found in the growth of the Institute's fund balances. These balances, net of borrowing, have increased substantially each year as is shown in the following table:

Fiscal Year	Increase in Book Value of Fund Balances
1991	\$151,402,000
1990	\$171,940,000
1989	\$117,226,000
1988	\$158,185,000
1987	\$156,143,000

The book value of the Institute's fund balances was \$1,678,988,000 as of June 30, 1991.

FINANCIAL PLANNING

The Executive Committee of the Corporation approves and monitors a four-year fiscal plan covering the current fiscal year and three years into the future. The current year portion of the plan is based on detailed budgets submitted by each of the Institute's departments. The responsibility for controlling expenditures within an account rests with the supervisor of the account, usually a faculty member or department head. Monthly account statements are issued which show both budget and actual charges. These accounts are monitored not only by the supervisor, but by the department head who has overall responsibility for the accounts within the department. Certain expenses are controlled centrally to assure conformance with the Institute's fiscal policy, contractual obligations to program sponsors or the donor restrictions. The Executive Committee continually reviews the fiscal plan, and any change to the plan requiring unrestricted funds in excess of \$25,000 must be approved by the Executive Committee.

This fiscal year was particularly volatile from a financial planning standpoint. The invasion of Kuwait in August of 1990 sent fuel prices soaring. The resolution of the conflict in the spring of 1991 brought stability back to prices. Overall the cost of energy exceeded the original budget by only \$800 thousand. However, during the year estimates of the potential overrun exceeded \$3 million.

The United States Congress began hearings on the appropriateness of indirect costs charged to Federal sponsors. Certain costs which are allowable under the current regulations were deemed "inappropriate" and moves to rewrite the regulations are underway. While these hearings did not affect MIT's 1991 finances, new regulations limiting the Government's participation in the sharing of research related expenses may have an impact on future financial plans.

CAPITAL BUDGET

At the end of the year the Institute's capital and major renovations budget was \$470.2 million. The project budgets include \$415.4 million for thirteen active projects and \$54.8 million for four future projects. These figures include land acquisition, construction, financing, and, where appropriate, funds to cover the unrestricted portion of building operating costs for ten years. Direct construction costs are \$264 million for the active projects and \$38 million for the future projects. The interest portion of the budget is estimated at \$136 million and will extend from ten to thirty years, depending on the project.

Major projects completed during the year include the renovation and expansion of the Rotch Library in Building 7 and conversion and the renovation of the 190 bed Edgerton House graduate student residence at 143 Albany Street. Also completed during the year was the construction of the South Hall Ring at the Bates Linear Accelerator in Middleton, Massachusetts. Renovations to the President's House at 111 Memorial Drive were also accomplished during the year. The work included modernization of heating, air conditioning, humidification, safety, and security systems as well as the provision for improved handicapped access to the building. Upgrading of the library storage facility at One State Street was begun and completed during the year. This building is the location of MIT's RetroSpective Collection containing over 500,000 printed volumes and 10,000 square feet of space for the storage of archives and manuscripts. Excavation and construction of the foundation for the new Biology Building at 31 Ames street was begun as was the addition of 6,600 square feet of new construction and the renovation of existing space at the Haystack Observatory in Westford, Massachusetts. The renovation of the building at 38 Memorial Drive to academic uses continues. This building will be used by the School of Management and the Dibner/Burndy Library, whose collections document the history of technology.

Total mortgage indebtedness for educational plant at June 30, 1991 was \$73,096,000 financed through the Massachusetts Health and Educational Facilities Authority.

FINANCIAL SYSTEMS

This year, the Budget Entry, Edit and Review System (BEERS) was enhanced to better support the analytical requirements of the office. Modules have been added to improve the monitoring of fund drafts and research data. The database has also been enhanced to include 15 years of historical budget data. Historical actual data is set to follow. Changes such as these have increased our ability to respond to special reporting and data analysis requests.

MITBUD continued to be used by departments for electronic submission of budgets. Additional reports and tools were provided to Budget Area Coordinators to analyze and adjust the submitted budget.

The need to expand tools for data analysis to better meet the informational requirements of the community is present. There is also a need to look into options for providing automated support for the Capital Budget.

PERSONNEL AND ORGANIZATION

Deborah L. Fairchild was chosen as one of two MIT employees to attend the School of Management's program for Greater Boston Executives. This was the first time in many years that any MIT staff members have been sent to the program. Her nomination and acceptance in the program recognizes the many contributions she makes to the financial planning and management of the Institute.

JOHN A. CURRIE

Office of Purchasing and Stores

Major projects accomplished or initiated this year include:

(1) EREQ System

EREQ is a free service of the Office of Purchasing and Stores. It is a universally available, on-line, interactive, integrated system that at present supports four major functions:

- **Electronic Requisitioning to Purchasing.** Users are able to create and instantly forward requisitions which do not exceed \$5,000 in value to the General Purchasing Office for review and purchase order issuance, usually within two hours.
- **Electronic Speed Orders.** If the value of an electronic requisition to Purchasing is \$500 or less, the user is able to specify the immediate assignment, on-line, of a purchase order number which he/she can promptly relay to the vendor.
- **Electronic Requisitioning to Office of Laboratory Supplies.** Users are able to create and instantly forward requisitions to the Office of Laboratory Supplies for order filling and delivery, usually the next day.
- **Access to Purchasing and Stores and Accounts Payable Systems' Information.** Users are able to get up-to-the-moment information on the status of requisitions, purchase orders, and invoices within the Purchasing and Stores and Accounts Payable databases.

We commenced an ongoing program of user training and implementation of the new EREQ system in May of the previous year. By June of this year, over 800 Institute requisitioners and administrators had become EREQ users. (A base of 3,000 to 5,000 eventual users is projected.) Use of the EREQ system increased significantly throughout this year. During the month of June, users logged-on to the system over 6,000 times, generating over 12,000 independent transactions to view the status of their business and to create 2,000 electronic requisitions and speed orders. These electronic requisitions and speed orders represented 45 percent of all requisitions (electronic and paper) which did not exceed \$5,000 that were processed through the General Purchasing Office that month.

In November, electronic requisitioning to the Office of Laboratory Supplies (OLS) was added to the EREQ system. Users are able to view the OLS on-line catalog of over 6,000 commonly used stock items for price and availability, and to create and instantly transmit electronic requisitions to the OLS for the items they require. The EREQ system automatically checks each electronic requisition for signature authority and account number validity, and instantly transmits the requisition to the stockroom or warehouse location(s) at which the required items are stocked. Use of the system (i) eliminates the need to transmit paper requisitions to OLS via the internal mail system, (ii) eliminates the manual processing and handling at OLS which paper requisitions require, and (iii) significantly improves order filling and delivery times.

In January, the Administrative Computing Steering Committee approved our proposal to continue the development of the EREQ system during this and the coming year to eliminate limitations and to increase functionality in the following areas:

- Elimination of \$5,000 limit per electronic requisition by providing requisitioners the capability to furnish source selection and pricing information on-line.
- Creation and transmission by requisitioners of electronic change requisitions.
- Creation and transmission by requisitioners of electronic requisitions which provide for blanket purchase order arrangements.

- Creation and transmission by requisitioners of electronic requisitions for radioactive items.

(2) EREQ Routing System

In January, the Administrative Computing Steering Committee approved our proposal for the development of an electronic requisition routing system (EREQ Routing system) during this and the coming year.

The EREQ Routing system will enable routing requisitions electronically (i) to account addressees, account supervisors, and/or others for multiple level reviews and approvals, as required and as may be stipulated for each account number; (ii) to other purchasing locations on-campus; and (iii) to other administrative offices for reviews and approvals, as required by MIT policies and procedures and Federal contract and grant regulations.

Electronic routing is essential because the EREQ system automatically limits user access and privileges to only the account numbers and dollar levels which the user's account supervisor has authorized (by granting formal signature authorization). Therefore, individuals with no signature authority are unable to create electronic requisitions, and individuals with low signature authority can only create electronic requisitions which total no more than their dollar level of signature authority. This is a severe limitation which is frequently a complaint of users and non-users of EREQ. Electronic routing will eliminate this limitation.

In addition, electronic routing will enable electronic requisitioning to Institute departments which are suppliers of goods and/or services (e.g. Physical Plant, Audio Visual, Food Services, Cryogenic Lab).

Initial testing of a limited function electronic routing system will commence in the spring of the coming year in conjunction with several organizationally diverse Institute departments. Full implementation of the EREQ Routing system is scheduled for the fall of 1992.

(3) Electronic Data Interchange (EDI) System

In January, the Administrative Computing Steering Committee approved our proposal for the development, during this and the coming year, of a prototype EDI system which would enable the transmission of electronic purchase orders from MIT computers to vendor computers, and the transmission from vendor computers to MIT computers of electronic confirmations and, if desired, invoices. EDI has the potential of improving productivity, and significantly expediting the purchase order placement process and the receipt of required goods and services. This will be evaluated through use of the prototype system with several of our high volume vendors.

(4) Implementation Of Barcode Technology

During the year, the Office of Laboratory Supplies implemented a new automated data entry system in two major stockrooms using barcoding and barcode scanners for supplies requisitioned in person at these high volume locations. Requisitions are processed faster and more accurately, billing errors are reduced, and data entry is automatic and no longer a separate operation.

General Purchasing Office

A major effort this year has been the promotion and support of the EREQ system, on a person-to-person basis and through visitations to high volume requisitioning departments and laboratories.

A major effort has also been the analysis of and adjustment to the impact of EREQ on workloads and methods and procedures.

EREQ has already had a major impact as a large and increasing number of low dollar requisitions have been eliminated from the office workload due to the popularity of EREQ's Electronic Speed Order function. By year-end, the staff of the office was reduced by 10 percent. Another 10 percent reduction is projected for the coming year.

EREQ notwithstanding, purchasing activity for the year continued at a high level. Of a total 77,000 purchase orders issued by all on-campus purchasing agencies (91,000 purchase orders issued, less 14,000 of which were electronic speed orders issued by EREQ users), the General Purchasing Office processed and issued 47,000 or 61 percent of the total.

Since the primary responsibility of the office is the purchase of required good and services at lowest practicable prices, major emphasis continued to be placed on negotiating discount agreements and other favorable pricing arrangements with suppliers.

Office of Laboratory Supplies

The office processed and filled 79,000 requisitions containing 233,000 line items of commonly used, standard items of supplies, tools, devices, and furniture and furnishings.

Combined sales of office and laboratory items and furniture and furnishings increased 9 percent over the previous year. Sales of office and laboratory supplies increased 1 percent and sales of furniture and furnishings increased 31 percent.

Minority and Woman-Owned Business Purchasing Programs

Business placed Institute-wide under these affirmative action procurement programs resulted in the award of \$14.8 million to minority and woman-owned business concerns. Over \$6.1 million was awarded to 434 minority businesses and over \$8.6 million was awarded to 953 woman-owned businesses.

Subcontracting Plans under Federal Contracts

Subcontracting Plans are required (by law) for each contract proposal to a Federal agency which exceeds \$500,000. The Subcontracting Plan specifically identifies the efforts that will be undertaken under a resulting contract to assure the award of a fair proportion of subcontract and purchasing dollars to small business concerns and small minority business concerns. The Subcontracting Plan includes both dollar and percentage goals which are negotiated with the sponsor and become a material part of the resulting contract.

As a service to departments, laboratories, and centers, the Assistant Director for Subcontracting and Government Relations coordinates with the Office of Sponsored Programs and principal investigators, prepares Subcontracting Plans for submission, negotiates changes when necessary, and reports accomplishments to Federal sponsors and principal investigators. This year there were 50 active Subcontracting Plans under Institute Federal contracts which necessitated the submission of over 100 separate reports of accomplishments to Federal sponsors. Additionally, in order to provide guidance and assistance to principal investigators, over 100 internal progress reports were issued.

There have been indications that Subcontracting Plan requirements may be extended to Federal grants also. In this event, we project that our workload in this area will more than double.

BARRY ROWE

Office of Registration and Student Financial Services

Several significant events can be recorded for the past year.

In the Bursar's Office, the trend toward lower default rates within the two federally supported educational loan plans continues. MIT's default rate on Perkins/National Direct Student Loans was 1.2 percent in 1990 (compared to 1.8 percent in 1989); the national default rate for that program decreased from 6.8 percent in 1989 to 6.2 percent in 1990. MIT's default rate on Stafford Student Loans was 1.8 percent in 1990 (compared to 2.2 percent in 1989); the corresponding national default rate increased from 14.7 percent in 1989 to 15.5 percent in 1990. Productive collection procedures at MIT which these numbers exemplify have been under continuing review and improvement over the last decade. Especially in the area of loans to foreign students, these procedures have increased our ability to collect from other countries. As a result, we were able several years ago to return over two million dollars from the Foreign Loan Reserve Fund to the Institute General Fund, and this year we have been able to return one third million more. Collectibles continue to increase at a faster rate than repayments, however, and further review during the next few years may result in the need to augment the Reserve Fund once again.

In the Registrar's Office, major efforts continue in the development of the new Student Information System (SIS) authorized by the Administrative Systems Steering Committee (ASSC) last year. During the Preliminary Analysis phase of this development plan, completed during the period covered by this report, available software packages for student systems were evaluated to determine their capabilities to satisfy our requirements, and the decision was made to use SCT's Banner Student and Financial Aid Systems as the base, although significant modification to it will be required. The completion of this phase led to approval and funding by the ASSC to undertake full development of the system on a DEC VAX. Both this hardware and the Banner software have been installed on campus and are operating in an investigative developmental mode, and the third, or System Architecture, phase of the project has begun.

In the Student Financial Aid Office we saw another year in the recently re-established trend toward increasing numbers of needy students in our undergraduate population, contributing toward an increase this year of about 9% in our total financial aid which now stands at \$39.2 million. But, after five consecutive years of an increasing percentage of freshman aid applicants coming from the lowest national income quartile, this percentage decreased slightly from last year's figure, the highest in our recorded experience. These percentages have been 11.8, 14.3, 20.2, 21.9, 22.6, and now 19.9.

In May, the Justice Department's anti-trust investigation of over 60 colleges and universities (upon which we initially reported briefly in last year's report) culminated in the filing of a Civil Complaint against the eight Ivy League Schools and MIT. Thereupon the Ivy League schools accepted a Consent Decree that severely impacts their financial aid policies and practices. MIT refused to accept the Decree on three counts: (1) it seems to direct colleges and universities opposite to the existing law and regulations that assure need-based distribution of federal financial aid programs—it requires abstinence from the activities that have served the schools well in their desire to carry out the spirit of that law; (2) it explicitly forbids discussion and exchanges among colleges and universities not only of student-specific awards, but also of the ways and means of practicing financial aid—an intolerable restraint upon any profession; (3) no determination has been made that any wrongdoing whatever has occurred in the aid profession—at MIT or elsewhere.

These events and accomplishments are discussed in further detail, and others reported, in the individual reports that follow from the Bursar, Registrar, and the Director of Student Financial Aid.

JACK H. FRAILEY, DIRECTOR

BURSAR'S OFFICE

Activities of the year were directed to improving current operations and being responsive to our clients:

All areas of the Bursar's Office participated in special projects related to development of and training on the new Student Information System; streamlining the short term (emergency) loan process; clarifying procedures for student withdrawals from enrollment; and developing a database to track student eligibility for and receipt of Stafford Student Loan checks, ensuring compliance with changed federal regulations. This latter project was the subject of a preliminary analysis just completed by Administrative Systems Development with substantial Bursar's Office input.

Responsiveness to students, parents, and alumni in the face of difficult economic times, without compromising our financial responsibilities, has also been a high priority this year. Students from Kuwait; U.S. students whose parents were unexpectedly called into military service; and alumni similarly called were three such groups dealt with this year. Our work was in cooperation with the Student Financial Aid Office and the Office of the Dean for Student Affairs.

Alumni Services

New federal Perkins Loan Program cancellation procedures were implemented by collecting addenda to promissory notes from borrowers.

Standardized procedures were implemented for refinanced interest loans which Technology Loan borrowers use to refinance accrued interest.

Formal responses to the Department of Education's proposed new regulations on the Perkins Loan Program and the Stafford Student Loan Program were made.

Student loans receivable totaled \$47,525,981 at fiscal year end. These notes were funded by \$13,199,084 of MIT loan funds established by friends and alumni of the Institute; \$22,361,590 of federal funds in support of the Perkins Loan Program; \$9,084 of federal funds borrowed to support a portion of our contribution to the Perkins Loan Program; \$8,856,223 borrowed from the Student Loan Marketing Association; and \$3,100,000 borrowed from local banks.

MIT's default rate on Perkins/National Direct Student Loans was 1.2 percent in 1990 (compared to 1.8 percent in 1989); the national default rate for that program decreased from 6.8 percent in 1989 to 6.2 percent in 1990. MIT's default rate on Stafford Student Loans was 1.8 percent in 1990 (compared to 2.2 percent in 1989); the corresponding national default rate increased from 14.7 percent in 1989 to 15.5 percent in 1990.

Financial Systems

This area of the office was reorganized in preparation for the Student Information System development project. Two positions were redefined as Programmer/Analysts and filled through promotion and attrition. Their responsibilities are to maintain the current student database during the transition phase and to ensure that our operational requirements are met by the new system.

Student Services

The quality of our interdepartmental relationships has greatly improved. Our participation in departmental student orientation sessions and participation by representatives of departments in our staff meetings have both increased. Policies and procedures have been improved, in particular with those programs that have joint administrative involvements, including Woods Hole, Health Sciences and Technology, the Harvard/MIT MD/PhD program, Draper Military Fellows, and the Sloan programs.

A number of upgrades were made to the student database to support our current operations. Computerized reports were developed to ensure compliance with changed federal regulations; reporting and posting of anticipated credits have improved; better computer reports have improved the registration hold and degree hold procedures; and several additional departments have received our assistance with their student billing problems.

Several improvements have been achieved in student accounting. Sponsors were billed and their payments received earlier than in past years. A system to facilitate the earlier posting of wire transfers to student accounts was developed (with the cooperation of the Investments Office). Scholarships and graduate awards were credited to student accounts earlier. These latter two improvements, while not improving cash flow to the Institute, increased the accuracy of our bills, resolved student situations earlier, and decreased student questions.

The quality of our publications continues to improve due to in-house electronic publishing.

Student tuition, fees, and other charges totaling \$173,811,223 were billed, an increase of 8.8 percent from last year. Servicing the 20,902 student accounts required 210,432 transactions to the student accounts receivable system. The amount collected as a percentage of the total receivable was 98.2 percent. The outstanding balance of all past due student accounts was reduced from \$1,655,116 last fiscal year end to \$1,232,641 this year, a decrease of 25.5%. Income from late payment fees was \$114,398; income from finance charges was \$180,208.

There were 267 active Parent Loan Plan accounts, of which 37 were new borrowers this year. A total of \$1,249,982 was disbursed during the year and \$1,580,403 in principal was collected. The PLP receivable at the end of the fiscal year was \$1,582,252. The default rate for the Parent Loan Plan (calculated as of June 30, 1991 using the formula for NDSL/Perkins Loans) is 0.5 percent.

The total student population supported by a sponsor (government, military, etc.) for the academic year 1990-91 was 641 students, representing total billings to sponsors of \$8,408,297.

Staff Notes

Cheryl Blankenship and Sandra Chauncey were teachers in Financial Operations' "Individual Development Planning" seminars.

Cheryl Blankenship, Sandra Chauncey, Ann Reilly, and Kate Wilson participated as group leaders in freshman orientation "Book Night."

Cheryl Blankenship was a panelist in an IAP seminar sponsored by the Women's Studies Program.

Cheryl Blankenship, Shirley Picardi, and Ann Reilly served as freshmen advisors. Sandra Chauncey, Janet Fischer, and Sue Wang assisted the Admissions Office by serving as readers of freshman applications folders.

Kate Wilson served as Chair of the Legislative Committee of the Coalition of Higher Education Assistance Organizations and testified on Reauthorization of the Higher Education Act before the House Subcommittee on Postsecondary Education and the Senate Subcommittee on Education, Arts, and Humanities in Washington, D.C.

Eleanor Wolcott served on the Conference Committee of the National Association of Foreign Student Administrators.

This has been a year of relatively little staff change:

Peter Brown, Associate Bursar/Information Systems, left in September for a position at Park Street Church in Boston.

Carolyn Bunker, Financial Officer, was promoted in September to Associate Bursar/Financial Systems. She assumed responsibility for managing the information systems area in addition to her financial responsibilities.

Barbara Doyle joined our staff in December as Analyst/Programmer III. She came from the United Nations in Geneva, Switzerland, where she was Consultant.

Ann Reilly, Assistant to the Bursar/Information Systems, was promoted in December to Analyst/Programmer II.

SHIRLEY PICARDI, BURSAR

REGISTRAR'S OFFICE

Enrollment

In 1990-91 student enrollment was 9,628, compared with 9,536 in 1989-90. This total was comprised of 4,389 undergraduates (compared with 4,307 the previous year), and 5,239 graduate students (compared with 5,229 the previous year). The International student population was 2,097, representing nine percent of the undergraduate and 33 percent of the graduate populations. These students were citizens of 103 countries. Students with permanent residence status are included with U.S. citizens.

In 1990-91, there were 2,593 women students (1,451 undergraduate and 1,142 graduate) at the Institute, compared with 2,519 (1,460 undergraduate and 1,059 graduate) in 1989-90. In September 1990, 362 first-year women entered MIT, representing 33 percent of the freshman class of 1,085 students.

In 1990-91, there were, as self-reported by students, 1,978 minority students (1,582 undergraduate and 396 graduate) at the Institute, compared with 1,798 (1,449 undergraduate and 349 graduate) in 1989-90. Minority students included 362 Black Americans (non-Hispanic), 27 Native Americans, 427 Hispanic Americans, and 1,162 Asian Americans. The first-year class entering in September 1990 included 451 minority students, representing 42 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1990-91 included 1,107 bachelor's degrees, 1,126 master's degrees, 41 engineer's degrees, and 497 doctoral degrees—a total of 2,771 (compared with 2,733 in 1989-90).

Tabular Presentation

Most of the above 1990-91 figures are taken from the several tables that follow this report. These tables, together with others dealing primarily with historical comparison and demographic data, comprise the annual Registrar's Report, separately published and available upon request.

Major Accomplishments for the Year

- **Strengthen support of the Institute's academic programs:** implementing a smooth transition to the new freshman pass/fail grading system in which students are graded on a P/D/F basis (with P meaning C or better performance); continuing to support academic departments in making the transition to the new undergraduate degree requirements; assisting the work of various Faculty Committees (e.g., in finalizing, finally, an evening exam policy; providing major support for updating the *Guide for MIT Undergraduates and Faculty Advisors*; and helping understand the credit and enrollments for music performance subjects, the academic credit earned during IAP, the number of HASS subjects completed by our students, and the extent to which the total work completed by graduating students exceeds minimum requirements); fulfilling a variety of requests for information and statistics;

Implementing the new academic calendar approved by the Faculty to address the serious end-of-term compression by extending the Final Examination Period to five days each term (including substantial communication with faculty and students about the unusual aspects of the calendar); revising policies and procedures to expedite the completion of the HASS, Phys Ed, and Writing Requirements by seniors; working with the Educational Studies Working Group to clarify policies and procedures for implementing the Privacy Committee's intent to decentralize their day-to-day oversight of privacy matters;

Revising the Registration Information booklet to clarify policies and procedures for various groups of students (freshmen, transfers, readmits, etc.) and to expand instructions regarding graduation requirements; enunciating a tuition refund policy for students called to active military duty; clarifying MIT's tuition tables, especially the communication of complex rules for early thesis completion; exploring alternative ways to do Final Exam scheduling so that the schedule could be announced shortly after Registration Day; making special preparations for the fact that Rosh Hashanah and Registration Day coincide this fall, and

communicating these arrangements to students and departments; working with Graphic Arts to provide class and recitation section lists that include pictures; and

Assisting with a variety of renovations to improve MIT's classroom facilities, especially with the Mathematics, Management, and Humanities departments (though lack of funds from the Campaign is seriously hampering efforts to make substantial progress in the classroom/lecture renovation program, but has led to the innovation of splitting the cost for various types of improvements).

- **Continue the major effort to develop a new Student Information System (SIS):** Accomplishments during the past year in the development process include (following the Productivity Plus methodology): completing the Preliminary Analysis phase of the development; making contractual provisions for maintaining/improving the current system during the development period; establishing management structures for project oversight and input by the various user communities; preparing a high-level implementation strategy—including staffing plan, cost/benefit analysis, evaluation of commercial student system software packages to determine their capabilities for satisfying our requirements, and investigation of technologies to increase automation; securing funding from the Administrative Computer Systems Steering Committee to undertake full development of a new SIS on a DEC VAX, using SCT's Banner Student and Financial Aid Systems as the base; negotiating final contracts for software/database licensing and substantial technical support (from SCT and Oracle) and for DEC hardware; installing the hardware, software, and communications; beginning the system architecture phase of the project to define in complete detail the specifications of the new system from the users' perspective; undertaking staff hiring, reorganization of responsibilities, and promotions in the Registrar's Office to get set for development of the new SIS; assisting other SIS user offices in searches for technical computer staff; holding a series of issues meetings to address particular policy questions; prototyping, in conjunction with Information Systems, a client-server application to provide student access to the SIS by Spring 1992, eventually leading to the full requirements of the new system for student access to a range of financial and academic information; and beginning a series of training sessions on the SCT package for a core group of SIS users.

- **Make improvements to the current Student Information System and Registrar's Office PC network:** completing the development of all programs and procedures to do Commencement Book and diploma processing on the PC network, and running the system through the full yearly cycle; participating in the development of a disaster recovery plan for critical functions of the SIS, including refinement of backup cycles and off-site storage for SIS operations tapes, as well as storage of 5th week and end-of-term tape records; making substantial changes to implement the new Pass/No Record system for freshmen; making major changes in the degree audit system to reflect the new degree requirements and provide students and departments with a projection of where the degree audit would stand based upon successful completion of current registration; assisting the Bursar's Office in developing better computer capabilities to deal with anticipated credits and in defining requirements for managing and monitoring GSL loans; refining the assessment of those expected to register in the next term; supporting monthly user meetings of staff from all areas using the SIS for the purpose of information exchange, coordination of operations, and discussion of issues that relate to the development of the new computer system; continuing to strengthen the local area PC network's capabilities to assist with development of the new SIS; and making a variety of programming updates to the SIS.

- **Strengthen effectiveness in administrative procedures and office operations:** initiating the development of a full operations calendar for the Registrar's Office, including the computer-related tasks of all offices that share use of the SIS; making major renovations in the Registrar's Office to accommodate the increased staffing and contract programmers required for the development of the new SIS; resubmitting a proposal to move the entire Registrar's Office back to the main building, and participating in the review of its feasibility; operating the new satellite Registrar's Office in the main building for a full year and assessing ways to more effectively provide services; undertaking a search to find a suitable software package to provide an ad hoc room scheduling process that gives better service to the community; working with the Communications Office to improve the design of the Commencement Book and the style/content of the MIT Catalogue; putting in place procedures to protect academic records in the Registrar's Office, including exploration of ways to ensure an off-site duplicate microfilm copy of all permanent academic records; installing an office security system; and working with Admissions and Bursar's Office staff to streamline and coordinate procedures for the admission, registration, and billing of Special Students.

Important Issues on the Agenda

- Move forward to complete development of a new Student Information System.
- Strengthen the academic research capabilities and involvements by the Registrar's Office in support of the Institute's educational programs.
- Establish more departments with terminal visibility to the SIS for their students and subjects; continue to develop ways of passing data electronically between the Registrar's Office and faculty/departmental offices.
- Establish a computerized room scheduling book capability; find a way to schedule Final Exams so that the schedule can be announced earlier.
- Work with the Planning Office and Dean for Undergraduate Education on an extensive renovation program for classroom/lecture facilities, to provide first-rate facilities at MIT.
- Secure space to move the Registrar's Office back to the main building so that we can more effectively support students, faculty, and the educational activities at MIT.
- Develop electronic certification and transcript processes so that students and alumni can get faster, more complete information about their academic records and attendance at MIT.
- Develop with the Institute Archivist a clear archival policy for the retention and protection of student records at MIT, including off-site storage of a microfilm copy of all MIT academic records.
- Undertake career development efforts to help develop the leadership, communication, and management skills of staff and support staff.

Staff Notes

Elena Martsinkovsky, Lauri Hugentobler, and Christiana Gerstner joined the Office as analyst programmers to help lead the development of the new SIS. Bonny Kellermann joined the staff as Associate Registrar, Academic Services, and Vicky Diadiuk as Associate Registrar, Curriculum Services. Several well-earned promotions were made to acknowledge significant and valued service to the Office: Elizabeth Bradley to Associate Registrar, SIS Production Operations; Mary (Jasinski) Callahan to Assistant Registrar, Schedules; Connie Scribner to Assistant Registrar; and Ri Romano to Assistant to the Registrar. Tom McCormack, who began as a student programmer, left MIT after a decade of service in the Registrar's Office. Norman Wright, who started as student programmer in the Office and now serves as consultant for maintaining the current SIS, received his S.B. in Philosophy from MIT in June.

DAVID S. WILEY, REGISTRAR

STUDENT FINANCIAL AID OFFICE

The High-Need Pattern Continues

Once again there was an increase in the number of needy students receiving aid. The extent of the increase moderated a bit from the past two years; the percentage of the freshman class coming from the lowest national income quartile, 19.9%, decreased slightly from last year's high figure, but remains high enough to suggest that we have not moved out of the high-need environment established at the turn of the decade.

These phenomena pushed the total need for financial aid to just over \$39,000,000; an increase of \$3,200,000 (9.2%). Forty-five more needy students were assisted than last year, and the average need for help rose, by

\$1,054, to \$15,550. In the aggregate, the financial aid program required \$18,900,000 from needy students' family resources, and provided \$39,200,000 in aid dollars. Thus the aid program again accounted for two-thirds of needy students' total costs.

Scholarships and Grants

The increasingly needy student body again produced a predictable increase in the need for scholarships and grants. That increase passed the quarter-million dollar mark for the first time. But the total realized from the usual designated scholarship resources was disappointing, and required significantly more supplementation from unrestricted funds than was expected. The amount realized from all three federal programs was less than last year, reflecting the stagnation of these programs. Although another healthy increase was added to the endowed scholarship principal, the amount of income realized in the past year from the endowment was less in percentage increase (6%) than last year's performance (19%). The total of current gifts for scholarships increased by 18%—but this is a relatively small line-item. Scholarship awards made directly to needy students by outside sponsors rose again, but only by one percent. Overall, the level of awards from designated grant and scholarship resources reached \$14.3 million, just 4.3% higher than last year. These resources once again fell far short of the need, and the program was augmented by \$11,618,000 from unrestricted income. The MIT Opportunity Grants Program, in its third year of existence, accounted for just over \$668,000 of this need.

The following table displays the sources of grants and scholarships received by needy students in the last three years:

Scholarships and Grants* (awarded to undergraduates with need)

Source	1988-89	1989-90 [‡]	1990-91
Pell Grants	\$ 837,000	\$ 933,000	\$ 901,000
SEO Grants	1,235,000	1,352,000	1,366,000
ROTC Scholarships	670,000	670,000	638,000
Scholarship Endowment	6,410,000	7,616,000	8,032,000
Current Gifts	821,000	1,096,000	1,277,000
Direct Grants	1,971,000	2,058,000	2,096,000
Unrestricted Funds [¶]	8,549,000	9,416,000	11,618,000
Total Grants Awarded	\$20,493,000	\$23,141,000	\$25,927,000

* All of the numbers reported in this section reflect awards from the academic year perspective, and so will not agree exactly with fiscal-year-based records reported by the Comptroller or the Treasurer.

‡ Some figures for 1989-90 have been updated or corrected since last year's President's Report was published.

¶ Including MIT Opportunity Awards and Special Program Grants.

Loans

During the year both undergraduates and graduate students borrowed more than last. At the undergraduate level, awards from the Technology Loan Fund increased minimally; loans from the Perkins Loan Program dropped noticeably—by about 14%—from \$3.2 to \$2.75 million; but the loans obtained from banks under the Stafford Loan Program made up for this drop, increasing 13% to \$5.2 million from \$4.6 million last year.

For a fourth year, the use of loan programs available for students' parents was only fitful, as parents either used conventional home-equity loans or found other means to pay college bills.

Graduate students borrowed less from the Technology Loan Program, but borrowing from the Stafford Loan Program increased; both MIT's involvement in the program and that of the commercial sector grew from last year's levels. Circumstances allowed us to offer graduate students loans from the Perkins Fund for the first time in several years; over \$800,000 was awarded.

The following table details loan use by undergraduate and graduate students:

Loans
(received by needy and non-needy students)

Source	1988-89	1989-90	1990-91
A. Awarded to Undergraduates			
Technology Loan Fund	\$ 912,000	\$ 1,151,000	\$ 1,162,000
Perkins/National Direct Loans	3,633,000	3,196,000	2,758,000
Stafford Student Loans	3,495,000	4,572,000	5,163,000
Sub-Total	\$8,040,000	\$8,919,000	\$9,083,000
B. Awarded to Graduate Students			
Technology Loan Fund	\$2,066,000	\$2,552,000	\$2,295,000
Stafford Student Loans by Commercial Lenders	3,622,000	3,239,000	3,513,000
Stafford Student Loans by MIT	790,000	571,000	1,082,000
Perkins Loans	0	0	827,000
PLUS Loans & Supplementary Loans for Students	167,000	94,000	181,000
Sub-Total \$6,645,000	\$6,456,000	\$7,898,000	

Work Programs

The off-campus job market showed a 7% percent decline in available jobs from the previous year, and all jobs were filled at a faster rate. The average starting rate for off-campus jobs was again well above the federal minimum wage. The on-campus minimum wage remained \$6.25 per hour, although it will rise to \$6.75 in 1991-92. The number of students working on campus showed no change.

The College Work-Study Program allocation again increased slightly above the 1989-90 level and was used entirely to subsidize the on-campus student employment program. As in the recent past, approximately half of the total 1990-1991 allocation was used to subsidize undergraduate work, and half to subsidize graduate student teaching assistantships.

The fiscal plight of the Commonwealth of Massachusetts has begun to erode the several state award programs at MIT. The Educational Employment Program, featured in last year's report, was one of the earliest casualties: funding was greatly reduced last year nearly to the point of uselessness, and is slated to disappear in 1991-92.

The Student Employment Office's computer-based "job board" fulfilled its promise last year, allowing us to record the jobs that come in by phone or mail, format output for display, track available opportunities and lessen the difficulty in producing data on job composition and tabulating statistics.

Other Programs of Interest

- Perhaps of most significance to the future of the financial aid profession and the way it evolves in practice was the change in direction taken in May by the Justice Department's anti-trust investigation of over 60 colleges and universities. A Civil Complaint was filed by the Department against the eight Ivy League schools and MIT. Almost immediately the national press announced that the Ivy schools had all accepted a Consent Decree that severely limits their freedom to discuss among themselves the professional aspects of financial aid policy and practice. MIT refused to accept the Decree, and remains the sole litigant in the Justice Department's suit. As the Attorney General foists his position on the nation via a willing press, MIT will be preparing its defense against one of the most ill-conceived attacks on the viability of need-based financial aid that the Institute has ever experienced.

- The Office continued our participation in the Student Information System upgrade project; there were significant site visits that contributed to the decision to purchase SCT's "Banner" financial aid module; and intensive training in the system has begun.
- Further significant improvements to the Stafford (GSL) Student Loan delivery system were planned and begun. This process is convoluted, involving repetitive interchange of information and paper among students, lenders, the guarantee agencies and the Institute's Bursar's and Aid Offices. Our aim is to use electronic processing tools to the maximum extent, not only to speed the process to completion for each student, but to strengthen the integrity of the process with respect to funds management and eligibility determination. To that end, the office is pursuing a project jointly with the Bursar's Office and the Massachusetts loan guarantee agency (MHEAC) to perfect a fully-electronic system, from application through certification and guarantee, to electronic transfer of funds to the Bursar.
- The SFAO continues to move more of our publications in-house, as we become more adept at "desktop publishing." This year most of our application forms and several information pieces were completely redesigned and produced by the staff.
- The year marked the provision of the fourth set of MIT Opportunity Awards, made to undergraduates from the lowest-income families. These awards are made to entering students, but are renewable in all four undergraduate years; so there will be members of all four classes in September 1991, holding these awards. The SFAO made Opportunity Awards to 89 of the new freshman class; there will be approximately 300 sophomores, juniors, and seniors in the program as well. These students are enjoying a significant reduction in the standard "self-help" (loan and job) expectation.

Staff Notes

During the year, both Donna Kendall and Kathie Nolan were promoted from Assistant Director to Associate Director.

LEONARD V. GALLAGHER, DIRECTOR

NUMBER OF STUDENTS BY COURSE AND YEAR, 1990-91 *

COURSE NAME	2	3	4	Grad.	Grad. Non-Res.	Grand Total	Course Number			
SCHOOL OF ARCHITECTURE AND PLANNING										
Architecture, IV	32	29	45	259	(6)	11	376 (6) IV			
Architecture, IV-B	2	3	3	-	-	-	8 IV-B			
Urban Studies and Planning, XI	3	3	2	168	(23)	27	203 (23) XI			
Total	37	35	50	427	(29)	38	587 (29) Total			
SCHOOL OF ENGINEERING										
Aeronautics and Astronautics, XVI	85	48	84	(1)	219	(11)	1	437 (12) XVI		
Aeronautics and Astronautics, XVI-B (Cooperative)	-	-	3	-	-	-	3 XVI-B			
Aeronautics and Astronautics, XVI-C (Internship)	1	12	17	-	-	-	30 XVI-C			
Chemical Engineering, X	65	56	43	220	(4)	1	385 (4) X			
Chemical Engineering, X-C	1	3	6	-	-	-	10 X-C			
Civil Engineering, I	11	17	29	265	(12)	4	326 (12) I			
Civil Engineering, I-A	8	11	20	-	-	-	39 I-A			
Civil Engineering, I-B (Environmental Engineering Science)	16	9	2	-	-	-	27 I-B			
Civil Engineering, I-W (Woods Hole)	-	-	-	3	-	-	3 I-W			
Electrical Engineering and Computer Science, VI	-	-	-	590	(33)	4	594 (33) VI			
Program 1-Electrical Science and Engineering	211	115	(1)	121	(3)	-	447 (4) VI-1			
Program 3-Computer Science and Engineering	114	66	69	-	-	-	249 VI-3			
Electrical Engineering and Computer Science, VI-A (Cooperative)	-	-	-	101	(1)	-	101 (1) VI-A(Co-op)			
Program 1-Electrical Science and Engineering	-	55	55	-	-	-	110 VI-1(Co-op)			
Program 3-Computer Science and Engineering	-	32	25	-	-	-	57 VI-3(Co-op)			
Electrical Engineering and Computer Science, VI-W (Woods Hole)	-	-	-	3	-	-	3 VI-W			
Materials Science and Engineering, III	35	12	(1)	14	(1)	189	(4)	250 (6) III		
Materials Science and Engineering, III-A	1	-	-	-	-	-	1 III-A			
Materials Science and Engineering, III-B (Internship)	8	28	28	-	-	-	64 III-B			
Mechanical Engineering, II	111	117	144	425	(26)	-	797 (26) II			
Mechanical Engineering, II-A	18	15	14	-	-	-	47 II-A			
Mechanical Engineering, II-B (Internship)	-	21	19	-	-	-	40 II-B			
Mechanical Engineering, II-W (Woods Hole)	-	-	-	1	-	-	1 II-W			
Nuclear Engineering, XXII	1	3	6	152	(3)	2	164 (3) XXII			
Nuclear Engineering, XXII-A (Internship)	-	1	3	-	-	-	4 XXII-A			
Ocean Engineering, XIII	3	4	4	82	(4)	1	94 (4) XIII			
Ocean Engineering, XIII-W (Woods Hole)	-	-	-	26	-	-	26 XIII-W			
Naval Construction and Engineering, XIII-A	-	-	-	40	-	-	40 XIII-A			
Ocean Systems Management, XIII-B	-	-	-	15	-	-	15 XIII-B			
Center for Advanced Engineering Study, EN	-	-	-	64	(64)	-	64 (64) EN			
Total	689	625	(2)	706	(5)	2,395	(162)	13	4,428 (169) Total	
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE										
Economics, XIV	29	31	45	132	(3)	6	243 (3) XIV			
Anthropology/Archaeology, XXI-Y	-	1	-	-	-	-	1 XXI-Y			
History, XXI-H	1	1	-	-	-	-	2 XXI-H			
Literature, XXI-L	1	3	4	-	-	-	8 XXI-L			
Music and Theater Arts, XXI-M	1	1	2	-	-	-	4 XXI-M			
Writing, XXI-W	-	2	2	-	-	-	4 XXI-W			
Humanities, XXI-D, XXI-P	-	-	1	-	-	-	1 XXI-D, XXI-P			
Humanities and Engineering, XXI-E	-	1	12	-	-	-	13 XXI-E			
Humanities and Science, XXI-S	1	1	7	-	-	-	9 XXI-S			
Linguistics and Philosophy, XXIV	-	3	4	(1)	59	(1)	2	68 (2) XXIV		
Political Science, XVII	3	13	14	131	(6)	40	201 (6) XVII			
Program in Science, Technology, and Society, XXI-T, STS	-	-	-	12	-	-	12 XXI-T, STS			
Total	36	57	91	(1)	334	(10)	48	566 (11) Total		
SLOAN SCHOOL OF MANAGEMENT										
Management, XV	27	39	45	538	(37)	4	653 (37) XV			
Management Fellows, XV-A	-	-	-	61	(3)	-	61 (3) XV-A			
Management-Operations Research, XV-B	-	-	-	27	-	-	27 XV-B			
Management-Ph.D., XV-P	-	-	-	79	-	-	79 XV-P			
Total	27	39	45	705	(40)	4	820 (40) Total			
SCHOOL OF SCIENCE										
Program in Applied Biological Sciences, XX	-	-	-	23	-	-	23 XX			
Biology, VII	50	68	(1)	85	185	(3)	2	390 (4) VII		
Biology, VII-A	-	6	17	-	-	-	23 VII-A			
Biology, VII-W (Woods Hole)	-	-	-	19	-	-	19 VII-W			
Chemistry, V	26	33	(2)	24	254	1	338 (2) V			
Earth, Atmospheric, and Planetary Sciences, XII	6	7	9	101	(2)	-	123 (2) XII			
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)	-	-	-	68	-	-	68 XII-W			
Mathematics, XVIII	37	43	40	120	(6)	11	251 (6) XVIII			
Mathematics with Computer Science, XVIII-C	11	13	19	-	-	-	43 XVIII-C			
Physics, VIII	75	54	60	(1)	315	(5)	1	505 (6) VIII		
Physics, VIII-A	15	5	15	-	-	-	35 VIII-A			
Total	220	229	(3)	269	(1)	1,085	(16)	15	1,818 (20) Total	
WHITAKER COLLEGE of Health Sciences and Technology										
Brain and Cognitive Sciences, IX	7	16	17	54	(2)	-	94 (2) IX			
Health Policy and Management, HPM	-	-	-	4	-	-	4 HPM			
Division of Toxicology, TOX	-	-	-	25	-	-	25 TOX			
Total	7	16	17	83	(2)	-	123 (2) Total			
Harvard-MIT Division of Health Sciences and Technology, HST	-	-	-	92	(74)	-	92 (74) HST			
Undesignated	83	26	(21)	-	-	-	109 (21) designated			
First Year	1,085	-	-	-	-	-	1,085	First Year		
Grand Total	1,085	1,099	1,027	(26)	1,178	(7)	5,121	(333)	118	9,628 (366) Grand Total
Not included in above totals:										
Foreign Study: 4 students in the third year, 6 students in the fourth year, 1 student in the fifth year. Domestic Study: 1 student in the second year, 1 student in the third year, 1 student in the fourth year.										
Non-Institute Brandeis	-	-	-	-	1	-	-	1 NIR		
Non-Institute Harvard	25	13	33	53	209	-	-	333 NIH		
Non-Institute Tufts	19	11	15	14	-	-	-	59 NIT		
Non-Institute Wellesley	1	25	23	42	-	-	-	91 NIW		

All figures include special students (special students also shown separately in parentheses)

ACADEMIC STAFF COUNT

	Professors *	Administration also Professors *	Institute Professors Emeriti Part Time *	Adjunct Professors *	Associate Professors *	Assistant Professors *	Sr. Lecturers and Professors Emeriti *	Sr. Lecturers	Lecturers	Sr. Research Scientists	Instructors	Technical Instructors	Sr. Research Associates	Postdoctoral Associates	Research Assistants	Teaching Assistants	Instructor Grad	Total	Visiting Professors	Other ¹
INSTITUTE PROFESSORS	9	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	1	-
SCHOOL OF ARCHITECTURE AND PLANNING																				
Architecture	10	2	-	1	7	9	1	1	15	-	5	1	-	-	12	68	2	134	6	14
Urban Studies and Planning	14	1	-	3	5	3	3	4	5	1	-	-	-	-	32	12	1	84	2	27
Media Arts and Sciences Sect.	3	1	-	1	4	5	-	-	-	-	-	1	-	-	73	-	-	88	1	5
Total	27	4	-	5	16	17	4	5	20	1	5	2	-	-	117	80	3	306	9	46
SCHOOL OF ENGINEERING																				
Aeronautics and Astronautics	17	2	-	3	7	6	5	3	11	-	-	3	-	2	142	9	1	211	1	10
Chemical Engineering	20	3	-	-	3	6	1	1	2	-	2	1	1	16	130	31	1	218	-	36
Civil Engineering	23	4	-	-	6	5	-	2	4	-	2	-	-	5	141	14	3	209	6	24
Electrical Engineering and Computer Science	56	14	-	3	27	14	9	1	9	2	-	4	-	2	346	104	4	595	-	18
Materials Science and Engineering	15	5	-	1	8	6	6	1	1	-	-	2	1	13	110	15	-	184	3	30
Mechanical Engineering	28	1	-	1	18	9	7	7	27	1	-	5	1	6	241	30	-	382	6	33
Nuclear Engineering	15	2	-	-	2	3	-	-	2	2	-	-	-	1	86	21	1	135	-	15
Ocean Engineering	13	1	-	-	7	-	1	3	8	-	-	-	-	6	58	8	-	105	2	8
Total	188	32	-	8	81	49	30	18	65	5	4	15	3	51	1,254	232	10	2,045	18	174
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																				
Economics	20	1	-	-	3	5	-	-	-	-	-	-	-	1	12	32	-	74	5	5
Anthropology/Archaeology	3	1	-	-	1	2	-	-	7	-	-	-	-	-	-	-	-	14	-	2
Foreign Languages and Literatures	3	-	-	-	4	-	-	2	17	1	-	-	-	-	-	-	-	27	8	1
History	4	1	-	-	4	1	-	-	1	-	1	-	-	-	-	-	-	12	4	1
Literature	9	2	-	-	3	3	-	-	6	-	-	-	-	-	-	-	-	23	1	-
Music and Theater Arts	6	2	-	-	2	2	-	3	13	-	-	4	-	-	-	-	-	32	-	10
Writing Program	3	1	-	1	2	1	-	2	12	-	-	10	-	-	-	-	-	32	-	4
Linguistics and Philosophy	14	2	-	-	3	3	-	-	-	-	-	-	-	-	12	7	-	41	-	21
Political Science	14	1	-	1	4	4	-	-	2	-	-	-	-	-	31	19	-	76	1	1
Program in Science, Technology, and Society	4	1	-	-	1	2	2	1	-	-	-	1	1	-	6	3	-	22	3	20
Total	80	12	-	2	27	23	2	8	60	1	1	16	1	1	61	61	-	356	22	67
SLOAN SCHOOL OF MANAGEMENT																				
Management	35	3	-	3	19	26	2	12	3	-	-	-	1	-	103	72	1	280	12	27
SCHOOL OF SCIENCE																				
Biology	29	3	-	-	12	8	-	1	-	1	3	1	-	51	31	-	-	140	-	78
Chemistry	24	2	-	-	4	4	2	-	-	1	-	1	-	35	144	47	-	264	1	77
Earth, Atmospheric, and Planetary Sciences	23	1	-	-	10	3	1	1	-	2	-	-	-	16	96	17	-	170	5	29
Mathematics	36	1	-	-	5	10	-	-	2	-	25	-	-	2	26	53	-	160	5	14
Physics	58	5	-	-	9	12	2	1	-	12	-	8	-	9	229	33	-	378	1	20
Total	171	12	-	-	40	37	5	3	2	16	28	10	-	113	526	150	-	1,113	12	218
WHITAKER COLLEGE OF HEALTH SCIENCES AND TECHNOLOGY																				
Brain and Cognitive Sciences	17	2	-	-	6	4	-	-	5	-	-	2	-	5	5	4	-	50	-	60
Toxicology	2	2	-	-	-	1	-	-	-	-	-	-	-	9	12	-	-	26	-	18
Total	19	4	-	-	6	5	-	1	5	-	-	2	-	14	17	4	-	77	1	78

Administration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
Aga Khan Program in Islamic Architecture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
Air Force Aerospace Studies	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	6	1	-	-	-	
Artificial Intelligence Laboratory	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	8	
Athletic Department	-	1	-	-	11	4	-	-	-	15	-	-	-	-	-	-	31	-	-	-	15	
Biotechnology Process Engineering Ctr.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	7	
Center for Advanced Engineering Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Center for Advanced Visual Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	
Center for Cancer Research	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	-	21	-	-	-	60	
Center for Cognitive Science	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	
Center for Environmental Health Sciences	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	4	-	-	-	3	
Center for International Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	
Center for Technology Policy and Industrial Development	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	13	
Center for Materials Research in Archaeology and Ethnology	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	
Center for Materials Science and Engineering	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	4	
Center for Real Estate Development	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Center for Space Research	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	4	-	-	-	6	
Center for Transportation Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Clinical Research Center	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	4	-	-	-	33	
Concourse	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	
Division of Comparative Medicine	-	1	-	-	-	-	-	-	-	-	-	5	-	-	-	-	6	-	-	-	17	
Energy Laboratory	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	16	
Experimental Study Group	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	5	-	-	-	-	
Francis Bitter National Magnet Laboratory	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	32	
Harvard-MIT Division of Health Sciences and Technology	2	-	-	-	2	-	1	1	6	1	6	-	1	2	60	-	-	82	2	-	39	
Haystack Observatory	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	1	
International Center for Research on the Management of Technology	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	
Laboratory for Computer Science	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-	4	-	-	-	22	
Laboratory for Electromagnetic and Electronic Systems	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	
Laboratory for Information and Decision Systems	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	4	-	-	-	8	
Laboratory for Manufacturing and Productivity	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2	-	-	-	9	
Laboratory for Nuclear Science	-	-	-	-	-	1	-	1	1	-	-	-	12	-	-	-	15	-	-	-	27	
Materials Processing Center	-	-	-	-	-	-	-	-	1	-	-	-	7	-	-	-	8	-	-	-	9	
Media Laboratory	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	15	
Medical Department	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	161	
Military Science	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	7	1	-	-	-	
Naval Science	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	7	2	-	-	-	
Nuclear Reactor Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	
Office of the Provost	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3	-	-	-	3	
Operations Research Center	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
Plasma Fusion Center	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2	-	-	-	18	
Project Athena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	
Research Laboratory of Electronics	-	-	-	-	-	-	-	-	1	-	-	-	8	-	-	-	9	-	-	-	63	
Sea Grant Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
Spectroscopy Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	
Statistics Center	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	
Student Activities	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	5	-	-	-	-	
Total	3	4	-	-	13	4	2	1	14	13	21	26	2	81	61	-	245	6	-	696		
Grand Total	532 ²	71 ²	8 ²	18 ²	202 ²	161 ²	45 ²	48 ²	169 ²	36	59 ²	71 ²	7	260	2,139	599 ²	14 ²	4,439	81 ³⁴	1,306 ³		
Faculty Ex Officiis *																				25		
																					4,464	

*Total Faculty 1,062

¹Includes Administrative Officers, Affiliated Artists, Coaches and Trainers, Guests, Honorary Lecturers, Institute Organist, Visiting Lecturers and Senior Lecturers, Medical Doctors, Nurses, Postdoctoral and Research Fellows, Postdoctoral Trainees, Research Affiliates, Senior Research Engineers, Visiting Economists, Visiting Engineers and Senior Engineers, Visiting Research Associates, Visiting Scholars, Visiting Scientists, Visiting Writers.

²Total Teaching Staff 1,997

³Not included in preceding total

⁴Visiting Professors include 37 Professors, 19 Associate Professors, 24 Assistant Professors, 1 Institute Professor.

NUMBER OF DEGREES AWARDED IN SEPTEMBER 1990, FEBRUARY 1991, AND JUNE 1991

	S.B.			S.M.			M.ARCH. M.C.P.			ENGINEER			PH.D.			SC.D.			TOTAL		
	S E P T	F E B R	J U N E	S E P T	F E B R	J U N E	S E P T	F E B R	J U N E	S E P T	F E B R	J U N E	S E P T	F E B R	J U N E	S E P T	F E B R	J U N E	S E P T	F E B R	J U N E
SCHOOL OF ARCHITECTURE																					
Architecture	-	-	-	-	-	-	-	7	21	-	-	-	2	1	4	-	-	-	2	8	25
Architecture Studies	-	-	-	-	1	17	-	-	-	-	-	-	-	-	-	-	-	-	-	1	17
Art and Design	1	3	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	42
Building Technology	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Planning	1	-	1	-	-	-	1	3	50	-	-	-	-	-	-	-	-	-	2	3	51
Real Estate Development	-	-	-	31	1	2	-	-	-	-	-	-	-	-	-	-	-	-	31	1	2
Urban Studies and Planning	-	-	-	-	-	-	-	-	-	-	-	-	3	2	3	-	-	-	3	2	3
Visual Studies	-	-	-	3	5	5	-	-	-	-	-	-	-	-	-	-	-	-	3	5	5
Total	2	3	43	34	7	26	1	10	71	-	-	-	5	3	7	-	-	-	42	23	147
SCHOOL OF ENGINEERING																					
Aeronautics and Astronautics	1	12	74	16	19	29	-	-	-	-	-	-	2	5	7	-	-	1	19	36	111
Ceramics	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Chemical Engineering	1	-	41	-	1	5	-	-	-	-	-	-	5	11	11	-	4	1	6	16	58
Undesignated	-	1	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5
Chemical Engineering Practice	-	-	-	12	11	8	-	-	-	-	-	-	-	-	-	-	-	-	12	11	8
Civil Engineering	-	5	22	13	20	26	-	-	-	1	1	1	4	6	7	-	1	2	18	33	58
Undesignated	-	1	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	10
Computer Science and Engineering	12	11	74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	11	74
Electrical Engineering	8	9	141	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	9	141
Electrical Engineering and Computer Science	-	-	-	30	35	90	-	-	-	-	7	12	14	19	19	-	-	1	44	61	122
Electronic Materials	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Environmental Engineering	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
Materials Engineering	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
Materials Science	-	-	-	1	1	3	-	-	-	-	-	-	-	-	-	-	-	-	1	1	3
Materials Science and Engineering	1	1	29	-	-	-	-	-	-	-	-	-	9	12	7	1	3	5	11	16	41
Mechanical Engineering	2	9	136	20	17	64	-	-	-	-	1	-	8	13	15	-	2	2	30	42	217
Undesignated	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Metallurgy	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Naval Architecture and Marine Engineering	-	1	2	4	-	11	-	-	-	-	-	-	-	-	-	-	-	-	4	1	13
Naval Engineering	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	8
Nuclear Engineering	-	-	4	6	8	10	-	-	-	-	-	1	2	3	13	-	2	1	8	13	29
Ocean Engineering	-	-	2	1	5	2	-	-	-	1	-	3	3	4	4	-	-	-	5	9	11
Ocean Systems Management	-	-	-	3	1	7	-	-	-	-	-	-	-	-	-	-	-	-	3	1	7
Polymers	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Total	25	50	558	108	122	266	-	-	-	2	9	25	47	73	83	1	12	13	183	266	945
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																					
Economics	1	2	45	-	-	-	-	-	-	-	-	-	9	4	13	-	-	-	10	6	58
Humanities	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Humanities and Engineering	-	1	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	10
Humanities and Science	2	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	4
Linguistics	-	-	-	-	-	-	-	-	-	-	-	-	4	2	2	-	-	-	4	2	2

Literature	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4		
Music	1	1	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5	
Philosophy	1	-	4	-	-	-	-	-	-	-	-	1	3	-	-	-	-	1	1	7	
Political Science	1	2	11	2	3	6	-	-	-	-	-	2	6	-	-	-	-	3	7	23	
Political Science and Public Policy	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	
Science, Technology, and Society	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Writing	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Total	6	7	88	3	3	6	-	-	-	-	-	13	9	24	-	-	-	22	19	118	
SLOAN SCHOOL OF MANAGEMENT																					
Management	-	-	-	6	30	268	-	-	-	-	-	6	8	5	-	-	-	12	38	273	
Management Science	3	8	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	8	38	
Total	3	8	38	6	30	268	-	-	-	-	-	6	8	5	-	-	-	15	46	311	
SCHOOL OF SCIENCE																					
Applied Biological Sciences	-	-	-	-	-	1	-	-	-	-	-	1	1	3	-	-	-	1	1	4	
Biology	-	3	75	1	-	-	-	-	-	-	-	3	7	14	-	-	-	4	10	89	
Undesignated	-	5	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	15	
Chemistry	-	1	22	-	1	2	-	-	-	-	-	12	13	14	-	-	-	12	15	38	
Earth and Planetary Sciences	-	-	-	2	2	1	-	-	-	-	-	-	-	-	-	-	-	2	2	1	
Earth, Atmospheric, and Planetary Sciences	-	-	7	-	-	-	-	-	-	-	-	6	7	4	-	2	1	6	9	12	
Mathematics	1	3	42	1	-	-	-	-	-	-	-	4	5	18	-	-	-	6	8	60	
Mathematics with Computer Science	-	1	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	17	
Physics	3	1	63	2	2	2	-	-	-	-	-	18	7	19	-	-	-	23	10	84	
Total	4	14	241	6	5	6	-	-	-	-	-	44	40	72	-	2	1	54	61	320	
WHITAKER COLLEGE of Health Sciences and Technology																					
Cognitive Science	-	1	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	16	
Brain and Cognitive Sciences	-	-	-	1	1	-	-	-	-	-	-	3	-	4	-	-	-	4	1	4	
Toxicology	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	1	-	2	
Health Policy and Management	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	
Total	-	1	16	1	1	-	-	-	-	-	-	4	2	6	-	-	-	5	4	22	
Harvard-MIT Division of Health Sciences and Technology																					
Medical Engineering	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	
Medical Physics	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	
Management of Technology																					
Operations Research	-	-	-	1	1	9	-	-	-	-	-	-	-	-	-	-	-	1	1	9	
Technology and Policy	-	-	-	3	4	12	-	-	-	-	-	-	-	-	-	-	-	3	4	12	
Transportation	-	-	-	6	3	5	-	-	-	-	-	-	-	-	-	-	-	6	3	5	
Without Course Specification	-	-	-	9	7	35	-	-	-	-	-	-	-	-	-	-	-	9	7	35	
Awarded Jointly with Woods Hole Oceanographic Institution																					
Biology	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	2	1	-	
Earth, Atmospheric, and Planetary Sciences	-	-	-	1	2	1	-	-	-	-	-	2	4	2	-	-	-	3	6	3	
Mechanical Engineering	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	
Ocean Engineering	-	-	-	3	-	-	-	-	-	5	-	-	-	2	-	-	-	8	-	2	
Grand Total	40	83	984	181	185	678	1	10	71	7	9	25	124	142	202	1	14	14	354	443	1,974

NUMBER OF WOMEN STUDENTS BY COURSE AND YEAR, 1990-91*

COURSE NAME	1	2	3	4	Grad.	Grad. Non-Res. ¹	Grand Total	Course Number
SCHOOL OF ARCHITECTURE AND PLANNING								
Architecture, IV		18	12	27	78	(2)	3	138 (2) IV
Architecture, IV-B		-	2	2	-	-	-	4 IV-B
Urban Studies and Planning, XI		2	1	1	74	(10)	11	89 (10) XI
Total		20	15	30	152	(12)	14	231 (12) Total
SCHOOL OF ENGINEERING								
Aeronautics and Astronautics, XVI		20	11	20	20	(1)	-	71 (1) XVI
Aeronautics and Astronautics, XVI-C (Internship)		-	3	2	-	-	-	5 XVI-C
Chemical Engineering, X		43	33	26	43	-	-	145 X
Chemical Engineering, X-C		1	2	4	-	-	-	7 X-C
Civil Engineering, I		4	6	8	50	(2)	-	68 (2) I
Civil Engineering, I-A		2	6	15	-	-	-	23 I-A
Civil Engineering, I-B		9	6	-	-	-	-	15 I-B
Civil Engineering, I-W (Woods Hole)		-	-	-	1	-	-	1 I-W
Electrical Engineering and Computer Science, VI		-	-	-	98	(3)	2	100 (3) VI
Program 1-Electrical Science and Engineering		49	24	25	-	-	-	98 VI-1
Program 3-Computer Science and Engineering		19	10	17	-	-	-	46 VI-3
Electrical Engineering and Computer Science, VI-A (Cooperative)		-	-	-	29	-	-	29 VI-A(Co-op)
Program 1-Electrical Science and Engineering		-	14	10	-	-	-	24 VI-1(Co-op)
Program 3-Computer Science and Engineering		-	3	8	-	-	-	11 VI-3(Co-op)
Materials Science and Engineering, III		18	5	(1) 8	55	(2)	-	86 (3) III
Materials Science and Engineering, III-A		1	-	-	-	-	-	1 III-A
Materials Science and Engineering, III-B (Internship)		5	17	14	-	-	-	36 III-B
Mechanical Engineering, II		22	28	32	57	(4)	-	139 (4) II
Mechanical Engineering, II-A		6	5	2	-	-	-	13 II-A
Mechanical Engineering, II-B (Internship)		-	4	5	-	-	-	9 II-B
Nuclear Engineering, XXII		1	-	3	16	-	-	20 XXII
Nuclear Engineering, XXII-A (Internship)		-	1	2	-	-	-	3 XXII-A
Ocean Engineering, XIII		1	2	-	8	-	-	11 XIII
Ocean Engineering, XIII-W (Woods Hole)		-	-	-	3	-	-	3 XIII-W
Naval Construction and Engineering, XIII-A		-	-	-	4	-	-	4 XIII-A
Ocean Systems Management, XIII-B		-	-	-	2	-	-	2 XIII-B
Center for Advanced Engineering Study, EN		-	-	-	7	(7)	-	7 (7) EN
Total		201	180	(1) 201	393	(19)	2	977 (20) Total
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE								
Economics, XIV		10	15	14	31	-	1	71 XIV
Anthropology/Archaeology, XXI-Y		-	1	-	-	-	-	1 XXI-Y
Literature, XXI-L		-	1	-	-	-	-	1 XXI-L
Music, XXI-M		1	-	1	-	-	-	2 XXI-M
Writing, XXI-W		-	1	1	-	-	-	2 XXI-W
Humanities, XXI-D, XXI-P		-	-	1	-	-	-	1 XXI-D, XXI-P
Humanities and Engineering, XXI-E		-	-	6	-	-	-	6 XXI-E
Humanities and Science, XXI-S		-	1	4	-	-	-	5 XXI-S
Linguistics and Philosophy, XXIV		-	1	1	19	(1)	-	21 (1) XXIV
Political Science, XVII		1	7	2	45	(6)	15	70 (6) XVII
Program in Science, Technology, and Society, XXI-T, STS		-	-	-	4	-	-	4 XXI-T, STS
Total		12	27	30	99	(7)	16	184 (7) Total
SLOAN SCHOOL OF MANAGEMENT								
Management, XV		9	11	19	126	(15)	-	165 (15) XV
Management Fellows, XV-A		-	-	-	7	(1)	-	7 (1) XV-A
Management-Operations Research, XV-B		-	-	-	12	-	-	12 XV-B
Management-Ph.D., XV-P		-	-	-	14	-	-	14 XV-P
Total		9	11	19	159	(16)	-	198 (16) Total
SCHOOL OF SCIENCE								
Program in Applied Biological Sciences, XX		-	-	-	11	-	-	11 XX
Biology, VII		30	38	53	72	-	-	193 VII
Biology, VII-A		-	2	8	-	-	-	10 VII-A
Biology, VII-W (Woods Hole)		-	-	-	13	-	-	13 VII-W
Chemistry, V		18	16	(1) 8	69	-	1	112 (1) V
Earth, Atmospheric, and Planetary Sciences, XII		3	4	5	20	(1)	-	32 (1) XII
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)		-	-	-	25	-	-	25 XII-W
Mathematics, XVIII		10	13	16	15	(2)	2	56 (2) XVIII
Mathematics with Computer Science, XVIII-C		3	3	6	-	-	-	12 XVIII-C
Physics, VIII		13	10	9	34	-	-	66 VIII
Physics, VIII-A		3	-	1	-	-	-	4 VIII-A
Total		80	86	(1) 106	259	(3)	3	534 (4) Total
WHITAKER COLLEGE of Health Sciences and Technology								
Brain and Cognitive Sciences, IX		3	7	6	10	(2)	-	26 (2) IX
Health Policy and Management, HPM		-	-	-	1	-	-	1 HPM
Division of Toxicology, TOX		-	-	-	12	-	-	12 TOX
Total		3	7	6	23	(2)	-	39 (2) Total
Harvard-MIT Division of Health Sciences and Technology, HST		-	-	-	22	(19)	-	22 (19) HST
Undesignated		35	11	(10)	-	-	-	46 (10) Undesignated
First Year		362	-	-	-	-	-	362 First Year
Grand Total		362	360	337 (12)	392	1,107 (78)	35	2,593 (90) Grand Total

*All figures include special students (special students also shown separately in parentheses); not included are: 3 students in the third year, 2 students in the fourth year on Foreign Study; 1 student in the second year, 1 student in the third year, 1 student in the fourth year on Domestic Study.
TOTAL UNDERGRADUATE WOMEN: 1,451

Office of Sponsored Programs

For fiscal year 1991, the total volume of sponsored research performed on campus approximated \$315,819. This represents an increase of 1.7 percent over fiscal 1990 volume of \$310,660 which was, in turn an increase of 8.7 percent over fiscal 1989.

Federal agency sponsorship increased by 1.7 percent (compared with 8.7 percent in 1990), with Department of Energy funding down almost .8 percent, the Department of Health and Human Services up 1.9 percent, the Department of Defense down 4 percent, the National Science Foundation down by .4 percent and the National Aeronautics and Space Administration up 23.0 percent.

Of the non-Federal sponsors, industrial funding increased by 4.6 percent, compared with an increase of 10.2 percent in 1990 and a increase of 18.8 percent in 1989. Support from private foundations and other non-profit sponsors decreased by 6 percent. It should be noted, however, that sponsorship characterized as non-Federal may include subcontracts which pass down Federal funds awarded to private sponsors under a prime contract with the government.

The breakdown by sponsor is shown in the following table:

CAMPUS RESEARCH VOLUME BY SPONSOR - 1985-1991
(in thousands of dollars)

<u>FEDERAL</u>		<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>
DOE	\$	56,363	54,511	55,062	55,629	54,045	61,098	60,625
DHHS	\$	40,252	45,735	47,310	49,070	52,565	57,915	59,025
DOD	\$	38,578	43,418	45,418	46,836	47,921	51,158	49,104
NSF	\$	33,658	36,772	38,091	39,177	38,962	38,093	37,953
NASA	\$	12,315	12,864	12,706	12,509	15,256	18,469	22,755
Other	\$	8,863	7,823	8,238	7,283	6,713	7,430	8,647
Federal Subtotal	\$	190,029	201,123	206,825	210,504	215,462	234,163	238,109
<u>NON-FEDERAL</u>								
Industry	\$	33,456	36,290	36,601	35,315	41,937	46,223	48,360
Nonprofit	\$	15,282	15,532	15,319	19,779	23,602	25,220	23,751
Other	\$	2,958	3,151	4,009	3,796	4,727	5,053	5,599
Non-Federal Subtotal	\$	51,696	54,973	55,929	58,890	70,266	76,496	77,710
<u>TOTAL</u>	\$	241,725	256,096	262,754	269,394	285,728	310,660	315,819

SIGNIFICANT DEVELOPMENTS

As in past years, a variety of continuing Federal developments and new events had an impact on sponsored research programs. Among these were the following:

Conflict of Interest

As noted in last year's report, the guidelines published by the National Institutes of Health during fiscal 1990 to address potential conflicts of interest in research supported by NIH grants resulted in a largely negative response from a variety of constituencies. As a result, they were withdrawn by the Secretary of Health and Human Services, who indicated that they would be reconsidered and reissued through formal regulatory procedures.

Over the last year, however, unexplained delays have prevented the reissuing of an NIH policy on conflicts of interest in spite of pressure from members of Congress who wish to impose additional regulations on the conduct of biomedical research. Those regulations would deal not only with conflicts of interest but also with such issues as misconduct in science, protection of whistleblowers, data sharing, access to data and elimination of any delays in publication of research data. This has led to scattered legislative initiatives which not only lack consistency but which also have no underlying consensus as to whether they should be implemented through university governance or outside control.

It is expected that new conflict of interest regulations will not be proposed by NIH until the General Accounting Office (GAO) has issued the findings of its study of university licensing practices, cited below. It is also anticipated that the new regulations will be limited to a narrower definition of conflicts, centering on the clinical trials of commercial products.

GAO Study of University Licensing Practices

As noted in last year's report, the General Accounting Office was asked by several members of Congress to examine the policies of the top university recipients of NSF and NIH funding to determine how issues of fairness and conflicts of interest were addressed in the licensing of research results. In fiscal 1991, after a pilot survey of five institutions, the GAO conducted a mail survey of 38 research institutions, including MIT, and followed up with on-site interviews with selected administrators and faculty. The GAO findings and recommendations have not yet been issued.

Research Assistant Tuition

Since 1984, MIT has charged the tuition of graduate student research assistants to the employee benefit pool rather than to the individual research projects on which they are employed. This was approved for MIT and several other universities by our cognizant audit agency, the Office of Naval Research, on the basis of the cost savings to the government and the incentive it provided for the use of graduate students in research. This practice has not been allowed, however, at institutions under the audit cognizance of the Department of Health and Human Services.

During fiscal 1991, the Office of Management and Budget was under pressure to extend the DHHS prohibition government-wide. As one of the universities most interested in continuing the practice, MIT communicated to OMB the reasons for its position, including the significant benefits to graduate education. At the close of the fiscal year OMB had not yet reached a decision, but it was subsequently announced that any definitive action by OMB would be deferred for a year to permit a more complete study of the issues involved.

Costs of Research

In March of 1991 Representative John Dingell (D-MI), Chairman, House Subcommittee on Oversight and Investigations, held a full day of hearings on indirect cost practices at Stanford University, with testimony from various Federal agencies as well as Stanford. The Subcommittee characterized the testimony as embarrassing and damaging in that it revealed numerous deficiencies in Stanford's cost allocation and charging practices and inadequate oversight by the Office of Naval Research. The Subcommittee thereafter broadened its inquiry and sent the cognizant audit agencies and the General Accounting Office, as well as members of its own staff, to selected major research universities, including MIT, to examine their indirect cost practices.

In May, 1991, Rep. Dingell held additional hearings on indirect cost practices which indicated deficiencies at other research universities. Although not as dramatic as those cited at Stanford, the disclosures were nonetheless damaging to the university community and received wide media attention.

In the aftermath of the hearings, a number of universities have repaid overcharges resulting from mistakes in the accounting or allocation process for indirect costs. In addition, OMB has published regulations designed to correct alleged abuses by clarifying existing cost principles or by excluding as unallowable certain costs which were not unallowable under those principles but which in the hearings were characterized as inappropriate.

The most significant consequence, however, has been a proposed OMB regulation which, among other things, would limit reimbursement of administrative costs to a maximum of 26% of modified total direct costs. The deadline for commenting on the rule was July 29, 1991, and in their responses many universities criticized the proposal as impacting in an arbitrary and unfair manner on responsible universities, compromising the traditional system based on full cost reimbursement, ignoring the increased cost of implementing federal regulations, and failing to address the problems which were actually identified.

Competitiveness and Foreign Countries

In recent years various inquiries have been directed at the extent of foreign sponsorship of research at US universities and the question of whether the transfer of critical technology to foreign companies is compromising U.S. industrial competitiveness.

In May, a faculty study group appointed by the Provost issued its report on "The International Relationships of MIT in a Technologically Competitive World." Chaired by Professor Eugene Skolnikoff, the report contained recommendations bearing on visiting faculty and scientists, commercialization of research results, gifts, licensing of MIT patents and formation of start-up companies, the industrial liaison program, public service and other programs, and the process by which faculty views should be sought on proposed international activities that raise significant questions.

Personnel Changes

Effective October 1, 1990, Maria Karatzas was promoted to Contract Administrator. On February 1, 1991, William Barrett and Anthony Favaloro were promoted to Senior Contract Administrator.

GEORGE H. DUMMER

VICE PRESIDENT FOR INFORMATION SYSTEMS

Each new generation of technology creates a more and more sophisticated audience for the services of Information Systems. The increased capabilities of the community and the technology have, paradoxically, heightened the demand on Information Systems for training, consulting, and other support services and the urgency to continually improve the skills of IS staff. Network connectivity has become an integral feature of the work and study life of many more MIT students, faculty, and staff. Computer networks are essential to their work. The question is no longer, "Do you use a computer?" Now, conversations start with, "How do you use your systems; what are your key applications?"

The year 1991 might best be described as a leap into the future for computing at the Institute on several fronts. The merger of Project Athena's service delivery functions and staff into Information Systems is the evidence of the leap that is most visible in the community. A number of other initiatives also propelled Information Systems forward. As illustrated by activities described below and in the reports of the IS departments that follow, Information Systems has begun to plan and act upon the realization that, fundamentally, our mission is customer service.

Merger With Project Athena's Service Delivery Functions

Project Athena began in May 1983 as a five-year sponsored program, later extended for three more years, to explore innovative uses of computing in the undergraduate curriculum. The project set out to create a computing environment that would make a lasting improvement in the quality of education at MIT. The charge was to explore diverse uses of computing in education and to build the foundation for strategic decisions about how computers fit into the curriculum.

In May 1989, the Provost appointed the Committee on Academic Computing for the 1990s and Beyond to "take a comprehensive look at the educational computing needs and possibilities for MIT's undergraduate and graduate students and faculty; establish objectives for MIT's educational computing; assess the technology which will be available in the 1990s; consider the costs and management of educational computing at MIT; and recommend options." The Committee reported to the Provost and the Academic Council in July 1990, recommending that MIT:

- "Actively encourage and support a suite of carefully targeted Educational Development Projects, in order to improve the overall level of teaching and learning and to prepare our students for the coming century;
- "Provide a stable, robust, and widely useful set of computational Basic Educational Services and Tools accessible from a carefully chosen set of computer types, over a pervasive network, in order to enhance and encourage both intellectual community and personal productivity among students, faculty, and staff; and
- "Organize appropriate facilities, support staff, management structures, and mechanisms for assessment and review of academic computing, in order to implement these efforts effectively."

After additional work by the committee to refine its proposal in the light of financial constraints, the Academic Council approved a plan in September 1990 which:

- Led to the creation of the Center for Educational Computing Initiatives, a research center reporting to the Provost, aimed at new innovative educational experiments;
- Merged Project Athena's service delivery functions into Information Systems, aiming to sustain service, despite funding reductions required by the shift to Institute support for instructional computing; and
- Will lead early in Fiscal 1992 to the formation of The Athena Consortium, externally funded, to continue Athena-related services for the distributed computing community at other universities and corporate sites.

Information Systems and Project Athena then began to define the structure of the merged organization. The results were:

- The creation of a new department, Academic Computing Services, to support faculty use of computing in their subjects, and to function as an advocate for academic computing at MIT;
- The merger of Athena's user services of consulting, training, and publications with similar functions in the Information Systems' department called Information Services, now renamed Computer Support Services; and
- The merger of Athena's system support activities, including software development and operation of servers and workstation clusters, with Network Services, renamed Distributed Computing and Network Services.

Transition to the new structure was completed several weeks before Project Athena formally ended on June 30, 1991. Budget limitations required the combined organization to be downsized by some 20 positions, and the transition process included outplacement assistance for the individuals in those slots. Most found other employment by June 30. By the end of Fiscal 1991, the combined staff were functioning in their new roles and hard at work preparing for the startup of the new academic year in September. Work will continue on porting the Athena Computing Environment to new platforms and on developing a collection of Basic Educational Services and Tools for use across a select set of hardware and software platforms, including systems running UNIX, Apple Macintoshes running MAC OS, and IBM Personal Computers and compatibles running DOS. Close ties are being developed with CECI.

Arrival of the VAX 9000

This spring Digital Equipment Corporation provided MIT with a VAX 9000, Model 420 VP, the centerpiece of a new research agreement to investigate uses of high performance computing in a distributed environment. The VAX 9000 is especially well-suited for the numerically intensive computing done by many of our faculty and students. We expect to integrate the 9000 seamlessly into the Athena Computing Environment and to evaluate its use as a compute server. The machine will be available to faculty, students, and staff for their work, both in the classroom and the research laboratory, on a wide variety of problems. The 9000 will complement the high performance computing resources of the MIT Supercomputer Facility, which will make a Cray X-MP available to the community early in Fiscal 1992.

Access Technology

MIT has worked over the past years to make it less difficult for individuals in wheelchairs to maneuver across the campus: curb cuts make it easier to cross the street, ramps enable entry into buildings, and a map shows wheelchair routes across the campus. Along with the ubiquity of computers comes the necessity to similarly make this technology useful to the differently abled. To this end, Computer Support Services has begun to assist individuals with special needs. They worked, for example, with a blind member of the staff to equip a computer with a Braille printer and to install software that speaks what is written in a file. They are working to provide alternative input devices for an individual who is confined to a wheelchair and has limited ability to move hands and arms. In the coming year, we will create a small access technology laboratory to expand our ability to serve faculty, students, and staff.

Telecommunications Systems Fiscal Success

Fiscal 1990 was a particularly difficult year financially for Telecommunications Systems. Unexpected fiscal complications associated with the acquisition and operation of the AT&T 5ESS switch, which provides voice and data communications to the campus, were a source of serious struggle. As a consequence of this experience, the department added its first Fiscal Officer to the management team. This year the team addressed the complex financial issues associated with the 5ESS and the department's role as a provider of the full range of services to the Institute community. Their hard work to make fiscal and service management a priority resulted in a Fiscal 1991 closing that is problem-free and in the announcement that there will be no general rate increase for telephone service in Fiscal 1992.

Microcomputer Center

Fiscal 1991 saw the Microcomputer Center, recently renamed the MIT Computer Connection, complete its seventh year of operation. Sales for the year approximated \$11 million on a product line that was expanded

this year to include Dell Personal Computers and Digital workstations. Negotiations are underway to add Sun Microsystems and IBM RS/6000 workstations to the product line next year. The MCC inventory, which is small, turned some seven times during the year without adversely impacting deliveries to customers, an inventory management feat of which we are very proud.

Information Security

MIT has decentralized responsibility for security management, relying on individual system managers and users to protect the information and computing resources in their domains. The Information Security Officer, based in Information Systems, is leading implementation of the Institute's information security program, which completed its second full year. The officer coordinates development of policies, assures compliance with them, and encourages awareness throughout the community. Among a number of accomplishments, Fiscal 1991 marked the completion of business continuity planning for the W91 data center and for the payroll system and its associated business functions, a critical administrative application. Continuity planning by all central administrative areas for all their functions that rely on the data center is underway by staff in those offices with our support.

Partnership With the MIT Libraries

After evaluating opportunities, MIT Libraries and Information Systems agreed to proceed with plans for a collaborative multi-year project to provide patrons with networked access to a broad array of library materials. In its early years the project will concentrate on identifying and exploiting a few key ways to deliver services electronically and to learn more about how people use them and how best to administer them. Project initiatives which will become available early in Fiscal 1992 include improved access from Athena workstations to the library catalog and to reference librarians as well as expanded catalog search for patrons who visit the libraries. In defining and pursuing project goals, the Libraries and Information Systems are working with other Institute offices, as well as with outside organizations.

Summary

Earlier in this report, I called 1991 a leap into the future of computing at MIT, because the year has been one of groundbreaking changes. We have changed the way the Institute manages academic computing. Major components of the computing environment are changing. We are changing the way Information Systems views our customers and their needs. During 1991, demand for change came from both inside and outside of our organization. We saw that our customers are the primary source of demand for innovations in our products and services, while our staff have been the primary source of process improvement ideas. Even those internal ideas must be sensitive to external realities. In the year ahead, we expect to listen more intently to our customers and to strive to continually improve how we serve them.

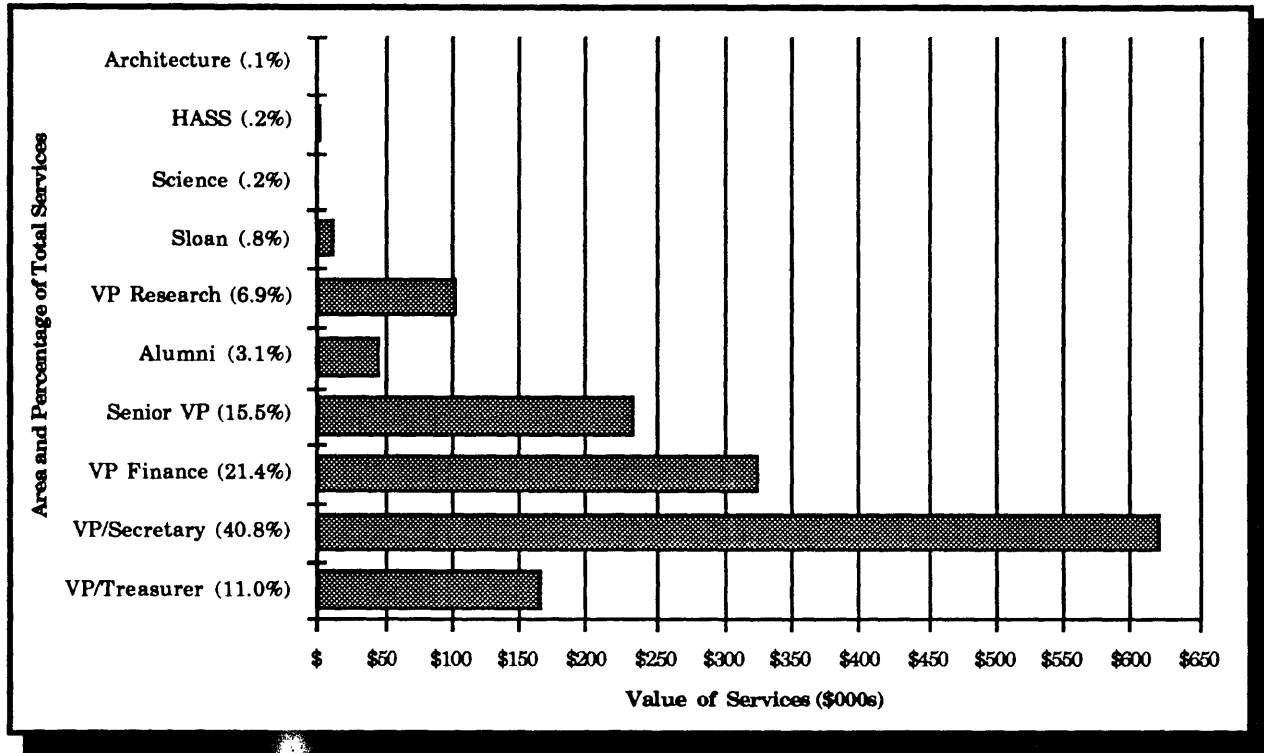
Personnel

A number of personnel changes occurred during the year. Of particular note is the appointment of Karen Hersey as Institute Intellectual Property Counsel. Karen's primary role is to counsel the senior officers in the establishment, interpretation, and application of Institute policies, procedures, and practices for the acquisition, ownership, dissemination, and responsible use of intellectual property.

JAMES D. BRUCE

ADMINISTRATIVE SYSTEMS DEVELOPMENT

The mission of Administrative Systems Development (ASD) is to provide application development and related services in partnership with administrative units that support MIT's research, educational, and business needs. Historically, this partnership was focused on the central administrative departments in the support areas of the Institute. In 1991, ASD expanded its client base to include administrative units within the schools and research sectors of the Institute. ASD worked on one or more projects in 1991 within the area of each of the academic/research senior officers, with the exception of the Dean of Engineering. ASD's billing revenues by senior officer are shown in the figure below.



ASD Revenue by Senior Officer, 1991
(excluding Information Systems)

While work for the academic and research departments was less than 10% of ASD's efforts for the year, it does represent a significant expansion of ASD's impact across the Institute. In addition to the new clients in academic and research areas, ASD worked with new client departments in the support areas, including the Bursar's Office, Office of Career Services, Quarter Century Club, Industrial Liaison Program (ILP), the Registrar's Office, and Endicott House. We believe that this trend will continue, as more and more departments recognize the need for professional, effective, and quality application development services.

Part of the impetus behind this trend is the fact that personal computers have become less expensive and more powerful. Many small offices are realizing the ability to use sophisticated, custom-developed systems that were once restricted to mainframes or minicomputers. In recognition of this, ASD in 1991 began to offer custom application development services for owners of Apple Macintosh and IBM Personal Computers. Following the same quality standards it uses for developing larger systems, ASD developed and supported personal computer applications for the Center for Materials Science and Engineering, Harvard-MIT Division of Health Sciences and Technology, Sloan School Dean's Office, Biology Graduate Office, MIT Japan Program, Center for Real Estate Development, Quarter Century Club, and Alumni Association.

Among the key larger projects ASD executed in 1991 were the Technology Licensing Office (TLO) and the ILP projects, both for clients new to ASD. For both offices, ASD first performed a preliminary analysis of the office business functions in line with the Productivity Plus system delivery methodology. This analysis was then followed by the designing and building of a new system for each client. The first release of the new TLO system was put into production in March, and has allowed the TLO to more effectively track the Institute's patents and licenses and the royalties associated with them. A second release of the system is expected to be placed into production in the fall. The ILP requested assistance from ASD to analyze its current system and recommend enhancements or a new system that would allow the ILP to better serve its member companies, faculty, and other MIT offices. The analysis was completed in the spring and brought to the Administrative Computing Steering Committee for review. The Committee gave its go ahead for the development of a new Corporate Relations/ILP system, and the design work commenced. The first release of this system is expected to go into production in 1992.

Another critical project undertaken by ASD in partnership with the Admissions Office was the Admissions Redevelopment Project (ARP). This project, which was modeled on the successful ADDS Efficiency Project completed in 1990, has redesigned and reprogrammed the database files and screens of the existing Freshman Admissions System. The goal of the project was to update the ten year old system with new technology and new functionality, while avoiding the expense of replacing the system in its entirety. In doing so, we extended the useful life of the system and have improved its quality and ease of maintainability, showing once again that some of the Institute's older, major systems can be given new life without the expensive cost of replacing them.

During 1991 a group composed of staff from ASD and Operations and Systems worked to enhance and expand the *ASD Quality Assurance Manual* in order to better integrate it with Productivity Plus. The existing quality assurance standards were improved and connected to Productivity Plus, and a section of the manual was added to incorporate the quality assurance process in ASD. The work on the revised manual was completed at the end of the year, and the manual will be distributed to other application development groups at the Institute and to other universities early in Fiscal 1992.

The staff in ASD continued their professional development through formal training classes and representing MIT at professional conferences. Over 250 person-days of skills training were delivered to ASD staff through classes on-site and away from MIT. An additional 180 person-days were spent by ASD staff at professional conferences both in the Boston area and around the country. This average of approximately ten days per employee was on target with our goal for the year of having each employee spend approximately two work-weeks per year in professional development activities. ASD also helped to address the professional development needs of members of its client community by organizing over 300 person-days of training to 57 programmers, users, and managers in nineteen client departments, at a cost to ASD of over \$25,000.

ASD this year launched a new seminar series targeted at managers, programmers, and others who use computers in administrative activities at the Institute. Ten two-hour seminars, ranging from an introduction to the Productivity Plus system delivery methodology to an overview of Computer-Aided Software Engineering (CASE) tools, were presented to an audience totaling over 200 people. Following the completion of the series, a survey of the attendees was conducted. The results were very positive, and ASD is planning on continuing its seminar series in Fiscal 1992.

Publication of *Developments*, ASD's quarterly newsletter targeted at administrators around the Institute, continues into its third year. The newsletter is well received by the Institute community, and has achieved its goals of both educating the community about the use of computers in administration and increasing ASD's visibility with potential new clients.

ASD will miss one of its long-term employees, Peter Flagg, who retired from his position as area manager in July, 1991 after seventeen years in Information Systems. In replacing Peter, the department's organizational structure was re-examined in the context of its Five-Year Plan initiatives. In July, 1991, the three area teams were merged into two. These two teams are headed by Joan Rastani (area manager in ASD since 1988) and Cynthia Golden, who will join ASD from Carnegie Mellon University in August 1991. In addition, a new team was created to focus on the department's business analysis and quality assurance activities. This team is led by Tim Dempsey, who previously headed one of the area teams in ASD.

The continuing initiatives in expanding the client base, working to improve the quality of the services provided, and reorganizing to better serve its clients have positioned ASD to be a premier service organization at MIT in the 1990s.

DONALD E. HELLER

INFORMATION SERVICES

Our mission is to plan, direct and deliver high-quality services for end-users of computing in the areas of equipment sales and service, as well as training, consulting, publications, and software acquisition. Faculty, students, and staff who compute at their desktops make up our client base. We aim to maximize the self-sufficiency of individuals, work groups, and departments, encouraging informed decisions about acquiring

information technology and effective use of it. We seek to promote convenient access to computer products and services at lowest possible cost. In 1991 Information Services staff focused on recovering the majority of our costs, on developing a strategy for supporting decentralized computing in a multi-vendor environment, on encouraging productive vendor alliances, and on promoting a work environment which fosters a productive and enthusiastic staff. Our effort has been carried out by six teams.

MicroComputing Resources (MCR)

The MCR, with four full-time staff and over twenty student employees, does direct consulting and troubleshooting support for callers on the help line. MCR staff work with the two dozen computer user groups which convene each month on campus. The MCR facilitates access for these groups to technical information and training; in turn, group members extend the reach of MCR technical staff by serving as local experts in their own offices. This year MCR staff began to work with members of the community who have special needs to evaluate and select appropriate equipment and software.

Microcomputer Center (MCC)

In its seventh year of operation, the MCC has added DEC workstations and Dell PC's to its existing Apple, IBM, and NeXT product lines, sold to members of the MIT community for both Institute and personal purchases. Negotiations are underway to carry Sun and IBM RS/6000 workstations soon. Sales for fiscal 1991 approximated \$11 million, up from \$9.2 million in fiscal 1990. As a result of streamlining operations, margins were reduced. The MCC very tightly managed its inventory, which is small and turned about seven times this year without adversely impacting deliveries to customers.

VAX Resource Center (VRC)

This group offers discount hardware and software services for DEC and Sun computers to a growing client base at MIT. There were 425 DEC Systems and 160 Sun systems registered for hardware maintenance; software services were acquired for 380 DEC systems and 225 Sun systems. DEC software library services were extended to Lincoln Laboratory this year, enabling Lincoln to reduce its costs. The VRC also negotiated a very cost-effective contract for future hardware maintenance of Athena equipment, and began implementing a fee-based program for Athena hardware maintenance.

Software Acquisition team

The team assumed responsibility for reviewing and negotiating all vendor software license agreements, working with MIT's Intellectual Property Counsel, in order to standardize the Institute's attention to this increasingly important area. The team added a number of new products to the specialty software available throughout MIT at greatly reduced prices.

Training Services

This year Training Services taught over 2,000 faculty, staff, and students in the Training Lab, in new courses on advanced topics, as well as standard offerings, short courses on Institute business functions, custom courses for departments, and evening thesis workshops. Our seminar series, attended by over 2,500, was expanded from a quarterly to a monthly schedule, with sessions about popular products, Quick Start classes, and vendor demos. In October, the IS Computer Training Catalog was awarded first prize by the American Computing Machinery (ACM) Special Interest Group on University and College Computing Services.

Publication Services (Pubs)

Pubs maintains an active publications program, ranging from quick reference guides to advanced applications manuals, to serve a diverse client base and support the communication needs of Information Services and other IS departments. This year Pubs produced ten issues of the *i/s* newsletter in its newly designed format. Pubs completed a major revision to *A Guide to Information Systems* and distributed it to key members of the MIT community. Documents produced by the Publications Services group received five regional awards from the Society for Technical Communication in 1991.

All of the teams are looking ahead to the coming year, as we confront the opportunities and challenges associated with merging Information Services and the staff and functions which supported end-user computing services in Project Athena into a new department, called Computing Support Services.

PENNY BLAISDELL

NETWORK SERVICES

Network Services operates MITnet, the campus computer network, and coordinates services from IS to network users.

Expansion of MITnet continued at a fast pace during the fiscal year as the number of computers on the network grew by 20% to over 4000. The network now carries, on average, over 8,000 electronic mail messages per day from all sources. Our client base includes most MIT departments and research groups. The Athena Computing Environment continues to be a primary client of MITnet with 1000 workstations that rely on the network for printing, on-line consulting, file service, electronic mail, authentication, and service management functions.

MITnet was extended to several new buildings during the year, including Buildings 7A, E17/E18, N51/N52, NW12/13/14, E1 (the President's House), E39, and N42. Network service is now available in most academic and administrative buildings on the campus. One of our highest priorities in the coming year will be to obtain funding to enable us to extend network services to the student residences. A proposal for the on-campus dormitories has been developed and will be reviewed with Housing and Food Services and others during the summer of 1991.

We pursued and accomplished several initiatives this year designed to increase the reliability, performance, and manageability of the network:

- A major upgrade to commercial FDDI routers was completed. With this upgrade the MITnet spine now operates at 100Mb/sec, using commercial technology and fiber installed during the installation of the Institute's 5ESS telephone switch three years ago. The new routers are technically capable of routing popular networking protocols such as AppleTalk and DECnet. During the coming year we will investigate the administrative and support issues related to providing these services.
- Development of network management software to monitor the state of the network and quickly detect developing network problems continues.
- Acquisition and installation of network hardware that can be remotely managed using the simple network management protocol (SNMP), an emerging industry standard, continues.

In the past, design of network connections has been a time-consuming task that delayed service delivery. In conjunction with Telecommunications Systems, during the year, we introduced unshielded twisted pair Ethernet (UTPE) service. This service has standardized the provision of network connections, allowing us to provide much faster turnaround on network designs and estimates and timely network installations at a standard price. We now provide many network installations in three weeks for a fixed installation charge and a monthly service fee. This service makes use of twisted pair wiring that was installed during the installation of the 5ESS digital switch three years ago.

During the past year we continued to improve the support services provided through the Network Help Desk. We implemented a new, improved process for network installations that results in improved customer service, developed a number of MITnet-related publications, introduced "bootstrap classes" for users new to the network, provided seminars for a number of Institute departments, and implemented a system for distributing software and documentation over the network.

We see an increasing demand for network-based services such as authentication and authorization, security, electronic signatures, electronic directories, access to library information and full text documents, information on courses and class schedules, electronic mail, job openings, etc. Services such as TechMail and Tech Info, described below, are in use at other universities. Our ongoing activities in the past year in these service areas include:

- **Privacy-Enhanced Electronic Mail.** We have done the basic technical and licensing work this year to enable us to introduce encrypted and "authenticated" electronic mail in the coming year. "Authenticated" mail provides the equivalent of an electronic signature, thus assuring the recipient of the identity of the sender.

- **TechInfo**, a network-based public information service. Software was introduced for information providers which makes it easier for them to input and maintain the information they provide to the service.
- **MITDIR**, the on-line staff and student directory, which now averages over 1400 electronic requests per day. During the year, we upgraded the functionality and reliability of this service.
- **TechMail**, an electronic mail facility for the Macintosh, is now used by over 600 individuals within MIT. During the year, we released a version of TechMail which extended access to those with Macs connected to MITnet via digital or analog phones. During the fall of 1991 we will release TechMail V2.0 with significant new features and incorporating standard Athena technologies such as Kerberos and Hesiod.

During the year, Network Services took an active role in planning the merger of Project Athena and Information Systems. The merger resulted in the establishment of a new department, Distributed Computing and Network Services, a melding of Network Services with Athena operations and development. Although this new organization will exist officially on July 1, staffs from the two departments began working together in April.

Of special importance this year was the Digital Equipment Corporation's grant to MIT of a VAX 9000/420 computer for use in research and education as part of the Athena Computing Environment. Staffs from Project Athena and Operations and Systems jointly installed the machine in April. It is up and running in W91.

Network Services staff continued to participate in professional organizations, such as the Internet Engineering Task Force, that work towards development of national and international networking standards.

CECILIA R. d'OLIVEIRA

OPERATIONS AND SYSTEMS

Operations and Systems (O&S)'s mission is to provide a central computing facility which insures the efficient delivery of reliable, accessible and secure computing resources and services in a distributed computing environment. O&S activities can generally be categorized as installation, maintenance, and client support. O&S offers general-purpose computing on two large IBM computers and provides training and consultation to the IBM client community. Additionally, O&S provides facilities management services to Institute departments to assist them in maintaining dedicated computer systems. Computers managed under such arrangements include: the MIT Supercomputer Facility's Cray 2, a DEC 8550 for Accounts Payable and Purchasing, a DEC 8530 for Physical Plant, a DEC 3600 for Electronic Requisitioning, and others.

Hardware Acquisitions

Operations and Systems responds to the growing computer needs of the Institute by installing and maintaining advanced hardware systems. Major installations for fiscal 1991 include: a new DEC 4000 computer to support the Personnel Office, a DEC 6510 computer to support the Registrar's Office, and a DEC 9420 computer to support the Athena Computer Environment. A Network Switching System (NSS) was installed to provide high-speed access between NEARnet and NFSnet.

Maintenance and Upgrades

Maintenance activities occurred in a number of areas during Fiscal 1991. One of the IBM 3083s, MITVMA, was upgraded from a model BX to a JX to provide for 37% more computer capacity and 33% more main memory. Two major conversions are also underway; the first is a conversion to the new cartridge tape drives that will take place over the fiscal year. Several applications will exceed that target. The second is a conversion from Xerox page printers to IBM page printers that has an expected completion date of January 1992. O&S also worked with Administrative Systems Development, the Communications Office, and the Technology Licensing Office to upgrade their departmental computer systems.

Chargeback and Business Continuity

In the area of customer support, O&S began long-term programs related to cost recovery, business continuity, and service improvement. To provide our clients with a more straightforward and predictable cost recovery method, O&S with the Administrative Computing Steering Committee (ACSC), overhauled the mechanism by

which computing resources are allocated and costs are recovered in administrative departments. One result was the formation of an Administrative Computing Resources Management (ACRM) committee that reports to the ACSC. The committee will monitor administrative computing usage and will perform capacity planning functions for MIT's administrative computing needs. This program will take effect in Fiscal 1992.

During the past year, O&S completed, with the Information Security Officer in Information Systems, a business continuity plan for the building W91 data center. Continuity planning for the payroll application were also completed during the year. Plans for other critical (registrar and admissions) and high priority applications will be addressed early in the next fiscal year.

In order to provide better services to our mainframe clients, O&S initiated a client satisfaction survey. Results of the survey generated a number of new initiatives, such as regular Client Forums that are designed to respond to current events and changes in the computing environment, improved help desk services, improved communications access to the mainframes, and increased mainframe training offerings at greatly reduced client costs.

Also during Fiscal 1991 we provided a color laserwriting service in building 11 and initiated a service to help clients convert from preprinted forms to more dynamic flexible and customized electronic forms for the large laser printers.

Statistics from MIT's Data Center:

Cycle Capacities:

20 MIPS (IBM)
39 VUPS (Vax Admin)*
1.6 GFLOPS (Cray)
80 VUPS & 250 MFLOPS (Vax 9420)

GBytes Hard Disk:	128 GBytes
Registered Users:	6,500
Tape Mounts:	100,000/yr
Pages Printed:	19,000,000/yr
Supported DBs:	30
Largest DB:	4.5 GBytes (new this past year)
Admin. Prod. Jobs (Client Services controlled only):	36,000/yr

<u>Production Machine</u>	<u>MIPS/VUPS/FLOPS</u>	<u>DASD GBytes</u>	<u># of Registered Users</u>
ED	1.6 GFLOPS	20	1361
VAX(Admin)*	39 VUPS	18	1527
MITVMA	8 MIPS	35	3600 (includes VMC)
MITVMC	12 MIPS	45	
PATRIOT	80 VUPS & 250 MFLOPS	10 12	

* Vax (Admin) includes EREQ, MITPPL, MITVAPS, MITVBUD, PERSON, and REGGIE.

Notes: MIPS = Million Instructions Per Second
VUPS = VAX Unit of Power
FLOPS = Floating-point Operations Per Second
GFLOPS = Billion Floating-point Operations Per Second
GBytes = Billion characters

ROGER ROACH

TELECOMMUNICATIONS SYSTEMS

This past year has been a rebuilding year for Telecommunications Systems. We researched outsourcing as a means of reducing MIT's telecommunications expenses. By outsourcing, we mean the selective transfer of some or most of the functions of the department to a third-party contractor. In this instance, we considered a variety of arrangements, including the sale of the MIT 5ESS switching system, and transfer of personnel to an outsourcing vendor. Responses from potential vendors indicated that telecommunications costs to MIT would actually increase under such an arrangement, perhaps by as much as \$6 million in the case of one proposal (before indirect cost recovery of approximately 50%) over the cost to MIT of operating the 5ESS over a ten-year period. Accordingly, a decision was made in September 1990 not to release a proposed outsourcing request for proposal.

A new relationship with AT&T that may be characterized as a strategic partnership flowed from the outsourcing effort. As a part of this new relationship, several new long term agreements were entered into. They provided for:

- Post-warranty maintenance of the 5ESS.
- Provisioning of dedicated service technicians.
- Operator assistance on 0+ calls from on-campus coin telephones, and non-sent paid calls placed over MIT's dial 190 lines.

These agreements will enable MIT to have a cost avoidance of \$800K over the life of the agreements. An additional annual cost avoidance of \$350K resulted from the reduction in the number and type of 5ESS incoming switched trunk lines.

In addition, MIT entered into an annual agreement with AT&T whereby AT&T routes inbound long distance traffic directly to MIT. This has created a new revenue source which will return approximately \$60K per year to MIT. (These fees are usually provided to the regional telephone carrier who interconnects long distance facilities to the end user.)

The department's administrative and financial performance was significantly strengthened by the appointment of Francie Davis as Fiscal Officer. Her financial expertise enabled the department to address the complex financial issues associated with the 5ESS and the role of the department as a service provider to the MIT community. The improved financial performance of the department is reflected in the April 12, 1991, announcement that there will be no general rate increases for 5ESS telephone service in fiscal 1992. Telecommunications Systems, in conjunction with ASD, completed the implementation of the ICE-9 release 4.1 software system. ICE-9 is an integrated telecommunications management system currently supporting the generation and tracking of 5ESS service orders, office equipment inventory and assignment, cable and wire inventory and assignment, call accounting, equipment and usage billing, and the generation and tracking of 5ESS station trouble tickets. In addition, the serving platform was upgraded from two DEC MicroVAX II computers to a DECsystem 5400. The upgrade has eliminated contention problems which previously plagued the older platforms and has significantly reduced service order assignment processing time from 20-25 minutes to less than one minute.

A number of enhancements to the 5ESS system were made this past year. Among them were the introduction of a limited number of V.32 modems within the 5ESS modem pool, which increases the data rate of dial-up connections to 9.6 Kbps and includes data compression and error correction. Further expansion of V.32 modems will be made in Fiscal 1992. In addition, an Ascend ISDN multiplexer was introduced in the Operations and Systems (O&S) dial-up service offerings to its customers. Dial-up traffic previously carried by 44 ISDN lines are now supported by only five ISDN lines by multiplexing multiple data calls on a single B packet-switched channel.

MIT's Octel Aspen Maxum voice mail system was upgraded to release 10, and the number of ports between the Octel and 5ESS systems were increased.

In support of the expansion of MITnet, Fiber Distributed Data Interface (FDDI) links were installed in buildings E19, E40, E1, E15, 54, 66, 11, W91, and NW12. An unshielded twisted pair Ethernet (UTPE) project was started this year with Network Services. The project utilizes the second four pair that was installed in conjunction with the 5ESS telephone project. Standard pricing and network management via simple network management protocol (SNMP) are two of the benefits of this project. Ethernet and AppleTalk installations were deployed in many buildings on-campus. A new off-campus sorority was wired for both voice and data and will receive 5ESS trunking and MITnet connectivity. Drops off of the MIT Cable Television drops were installed in buildings E1, W20, 20, E38, 10, 11, and 37.

The department surveyed 137 of its MIT customers to assess their satisfaction with the services Telecommunications Systems provides and their overall perception of the the department. The sample represents a cross-section of the academic, research, and administrative community. The survey results, which identified a number of service deficiencies, will be used to develop action programs to correct those deficiencies.

Telecommunications Systems participated in the New England Telephone (NET) message unit restructuring case currently before the Massachusetts Department of Public Utilities. Working with others in the initial phase of the case, MIT avoided an annual increase in message unit costs of approximately \$500K. Following the DPU's order of October 5, 1990, NET worked collaboratively with MIT to determine a new rate structure for local calls, which are now incorporated within a February 7, 1991, tariff filing. The DPU is expected to rule on the filing on or before September 9, 1991. MIT would see a modest decrease in local usage costs should the DPU approve the filing.

MORTON BERLAN

SENIOR VICE PRESIDENT

This year marked the first full year of operation since completion of improvements made under Phase I of the Institute's shared savings Electric Rebate Program. Throughout the year, rebates of over \$1.1 million were realized as a result of a reduction of approximately 18 million kilowatt hours of electricity used. In spite of these significant results, it was not deemed worthwhile to further extend participation in Phase II of this program due to changing ground rules and the likelihood of our proceeding with the construction of a cogeneration facility.

Due to three separate incidents of wide spread black-outs this year, the reliability of the joint Cambridge Electric Light Company (CELCo)/MIT primary distribution system was questioned. Analysis of the outages disclosed some significant concerns with the basic design and operating philosophy under which the campus is served by CELCo. After a series of meetings with management and the engineering staffs from both organizations, equipment changes and operating procedures which address the problem were implemented.

Major design and construction activities this year included continuation of design work on the new Biology Project; installation of air conditioning, the provision of handicapped accessibility, and the upgrading of the heating, electrical, and fire/safety systems, all at the President's House; and major improvements to egress systems at Senior House. Renovation work also continued at 477-479 Commonwealth Avenue, which will serve as MIT's first sorority house.

A new 5-year food service contract was signed with ARA Corporation. The new agreement, entered into after a lengthy competitive process, is based on a profit and loss concept instead of the traditional cost plus fee basis, thereby providing incentive for customer service, responsiveness, to changing needs, and food selections tailored specifically to MIT's needs.

Affirmative action efforts continued this year. Once again, our efforts focused on attracting more minorities and women to administrative staff and management positions and attracting women to the various jobs which have been traditionally male dominated. Consonant with these goals, a woman was promoted to the position of Assistant Director of Physical Plant for Construction and Space Management. During the last two Affirmative Action reporting periods, nine underrepresented minority individuals were hired. While none of these positions were in the administrative staff category, we are committed to the Institute's Affirmative Action goals and will continue to strive to attract more candidates to these positions.

Following are individual department reports.

WILLIAM R. DICKSON

Campus Activities Complex

In keeping with its mission, the Campus Activities Complex (CAC) continued to provide operational support for events on campus. Over the course of the year, the department coordinated over 7,000 scheduled events which were attended by approximately 311,000 people. Major events included the Inaugural Festivities, the 1991 Commencement Ceremonies, the Media Lab's Fifth Anniversary Celebration, and Julius Stratton's 90th Birthday Party.

New programs and expanded services highlighted the year. The Student Center Committee introduced a weekly entertainment series in its 24 Hour Coffeehouse. The Stratton Student Center Information Desk provided updated event information to the MIT community through the on-line computerized Tech Info Service. The Hobby Shop improved its machinery and, through a generous contribution from an alumnus, extended its evening hours. The MacArthur Foundation graciously contributed a gift toward the endowment of the Wiesner Student Art Gallery.

During the winter, events relating to the Persian Gulf War resulted in a broad range of educational programs and activities for the community. In particular, the CAC staff assisted in advising student organizations and community groups with interests in all aspects of the war. Also in support of student leadership, the CAC hosted a Regional Conference of the Association of College Unions International in conjunction with the Student Center and Lecture Series Committees.

As a special community event, the CAC coordinated the MIT exhibition of the AIDS Quilt in cooperation with the Boston Names Project. During the three-day event, over 25,000 people from MIT and surrounding communities viewed the quilt and participated in educational programs on AIDS.

Operationally, the department continued its assessment of facility usage and maintenance. Renovations within CAC facilities included the Walker Memorial darkroom and dance studio, WMBR Studios, Stratton Student Center Reading Room and fifth floor lounge, as well as the CAC and Food Service administrative offices.

The CAC bade a fond farewell to two devoted members of the department and MIT community who retired after many years of extraordinary service. Conor Moran, Associate Director of the CAC, retired after 30 years of service and George Pishenin, Technical Instructor and Director of the Hobby Shop, retired after 39 years.

PHILLIP J. WALSH

Campus Police

The MIT Campus Police Department continued to serve the community with 24-hour professional police and emergency medical services. In addition, the Crime Prevention Unit and Special Services Division continued to provide crime prevention education and assistance for minor legal problems of extenuating circumstances such as landlord/tenant disputes, consumer fraud, small claims court cases, and abuse and harassment situations.

There were a total of 1,858 complaints (situations which required the recording of an incident by a police report) recorded this year, a 5 percent increase over last year. Of these complaints, 23 were in the crimes against person category. Campus Police officers made 119 arrests on MIT property this year.

Larceny again continued to be the largest category of crime with which the Institute had to contend this year. The total number of reported incidents of larceny was 179 and the total dollar loss was up 89 percent over last year for a total of \$321,497. Computers and computer components were, once again, the most frequent type of Institute-owned property stolen.

Personal property (non-residence) thefts were up 10 percent with 306 incidents totaling losses of \$63,908. Wallets and purses again led the list of items stolen.

The number of residence hall losses was up with a total dollar loss of \$29,925.

Motor vehicle thefts increased this year for a total of 55 vehicles stolen.

Emergency medical services increased 43 percent this year for a total of 2,546 runs (including emergencies, transfers, and medical shuttles).

The Campus Police provided 5,276 personal safety escorts during the year.

The MIT Campus Police Department looks forward to continuing to provide the community with professional police and emergency medical services in the coming years.

ANNE P. GLAVIN

Endicott House

A major effort this year involved the continuation of planning for the construction and installation of life safety improvements in the main house. Working with the Safety Office, accomplishments to date include the installation of sprinklers in the basement and attic levels, the installation of a modern fire alarm system, hook-up of a direct line to the Dedham Fire Department, and the purchase and installation of a standby electric generator. To complete the project, the main staircase will be enclosed, the sprinkler system extended, other early warning devices installed, and various doors re-swung for egress purposes. Since these requirements could have a major impact on the appearance of the house, an architect was commissioned to study the problem and make appropriate recommendations. This portion of the project is scheduled to begin during the summer and continue well into next year.

During the year a meeting was held with neighbors and abutters of a five-acre parcel of land given to the Institute by Russell Stearns several years ago. The Institute is considering selling the parcel for residential development and the purpose of the meeting was to inform the neighbors. Proceeds from the sale will be used to endow a fund for capital improvements at Endicott House.

Final transfer of the Stearns Estate, a 13-acre parcel of land adjacent to Endicott House and willed to MIT several years ago by Russell Stearns, appears to be imminent. The question remains as to what to do with the property once ownership is actually transferred.

Fewer capital improvements were made during the year because of a decrease in business due to the weakened economy. Projects which were deemed essential and were completed include repairs to the slate roof of the main house, installation of a septic system for the caretaker's cottage, repairs to the main house window security grates, structural repairs and reroofing of the water tower, and removal of an underground gas tank for environmental reasons.

From a statistical standpoint, the facility was used 276 days and 180 nights by 194 groups. Last year's usage was 238 days and 165 nights by 211 groups. There were 83 groups affiliated with the institute, 55 from the non-profit sector, and 56 corporate groups. There were 37 overnight conferences lasting from one night to the School of Management's nine-week Senior Executive Program. Groups affiliated with the Institute accounted for 21 of these residential groups, seven were from the non-profit sector, and the remaining nine from corporate businesses. There were 6,256 overnight guests and 24,621 meals served during the year compared with 6,718 overnights and 25,853 meals last year.

HOWARD F. MILLER

Graphic Arts and Audio Visual Services

This year total income for all Graphic Arts Services was \$6.1 million, a decrease of 3 percent compared with last year. In spite of the fact that a higher percentage of work was completed in-house in the Offset Printing and Binding Department because of new equipment purchases made during the past two years, income was down 10 percent over last year. The volume of work in the Illustration Department declined by 35 percent due to the continuing increase in the use of personal computers. Income generated by the Copy Centers increased by 4 percent.

A very successful Open House was held in the main building of Graphic Arts in February. Many members of the MIT community were able to observe the new two-color Heidelberg press and other new equipment in operation.

A new sound system was installed in Walker Memorial (Morse Hall).

JAMES W. COLEMAN

Housing and Food Services

The new graduate student residence located at 143 Albany Street, which opened last year, was named Edgerton House in memory of Harold "Doc" Edgerton. The design and operating concept of this building has been enthusiastically received by the students making it the most popular housing option in the graduate housing system.

The first year of a plan to house all new graduate students was implemented and all indications are that MIT should be able to guarantee housing to all incoming graduate students who wish Institute housing by the fall of 1994. Renovations to Tang Residence Hall, necessary to convert this building to a first-year graduate residence, are on schedule for completion in August of 1993. The graduate housing assignment process continues to be reviewed and developed to insure full use of our existing graduate student housing resources.

The Housing Office implemented a Graduate Coordinator Program for Eastgate, Westgate, Tang Residence Hall, and Edgerton House. The program involves hiring a graduate student for each building to act as liaison between the residents and the Housing Office to assist in addressing student needs from their perspective. This also enables the Housing Office to offer services to the graduate student population and to families of graduate students to better acclimate them to the MIT community.

Commencement of renovations to Senior House represented the most significant project in the undergraduate housing system. The project consists of enclosing stairwells, removing and/or relocating walls for direct access to fire escapes, and the installation of additional emergency lighting. Completion is expected in August of next year.

Food Services continued to make significant gains in services and cost reductions and highlighted the year by producing a new food services contract for the next five years. The contract bid process involved eight food service contractors and the ARA Corporation was awarded the contract. Their proposal best addressed the goals set by Food Services for serving the 18,000 member MIT community. The new agreement is contracted on a profit and loss basis, providing incentive for customer service, responsiveness, and a food choice tailored to MIT's needs. Food service units included in the new agreement are the dining rooms in our residence halls; Lobdell; Networks, which will be reoriented more toward student interests, Walker Memorial, and the Faculty Club. The arrangement breaks new ground while continuing to provide students with unique freedom in selecting dining times and locations.

LAWRENCE E. MAGUIRE

Insurance and Legal Affairs

During the year, the Insurance and Legal Affairs Office moved its reporting responsibility from the Treasurer's Office to the Office of the Senior Vice President. However, all essential operations of the office remain the same.

The office continued to purchase "All Risk" type property insurance to cover all of the Institute's property. The total value insured was slightly over \$1.6 billion, and the cost for this coverage was approximately \$500,000.

The Institute's fleet of approximately 225 vehicles was insured at a cost of \$145,000.

The Institute continues to obtain most of its general liability coverage from the commercial marketplace. However, steps have been taken to prepare the MIT captive insurance company to accept a greater share of this coverage, with the ultimate goal that the Institute will eventually fully self-insure in the primary liability area. This is all part of our effort to self-insure or insure through group captive insurance companies, risk retention groups, or group purchase mechanisms in order to control costs and insulate the Institute from the cyclical fluctuations of the insurance marketplace. This year's cost for liability insurance, including catastrophic coverage, was approximately \$1.4 million.

Over 160 claims representing property losses by the Institute or attributable to liability of the Institute were processed this year. Reimbursements to the Institute for property losses totaled \$160,000 and payments on MIT's behalf were approximately \$70,000.

Over the course of the year, this office responded to over 100 requests for legal assistance. These requests covered a broad spectrum of legal issues but focused mainly on landlord/tenant matters, employment issues, personal debt, automobile accidents, family matters, immigration status, and some criminal charges. About 60 percent of these requests were from undergraduate students with the remainder from graduate students and other members of the MIT community.

THOMAS R. HENNEBERRY

Office of Facilities Management Systems

During the year, the Office of Facilities Management Systems (OFMS) continued to strengthen its space accounting, system development, and consortium support functions. The office's space accounting activity includes the operation and maintenance of the MIT/OFMS-developed space accounting systems, INSITE and INSITE-CAD, which are used in the inventory of the Institute's more than nine million square feet of owned and leased academic buildings. This includes such ancillary services as field audits, room number assignments, indirect cost and other report generations, historical record keeping, and floor plan maintenance.

The INSITE Consortium experimented with the sharing of a stand-alone version of the INSITE-CAD system with the University of Utrecht in the Netherlands. As the result of this experiment, a larger pilot program has been developed which will link users of the INSITE-CAD system to their own smaller database systems.

Throughout the year, the OFMS systems development team has been focusing on two specific projects. The first is the transfer of the mainframe INSITE functionality to a workstation environment. The second project is in response to the increased demand from the MIT community for viewing our electronic floorplans for management and administrative purposes within their own departments. The database is being reorganized to accommodate its future use in the world of Macintosh in addition to the current PC platform that the system now uses.

The educational aspects of OFMS have continued to thrive both here and abroad. The Office continues to attract senior executives to its semi-annual facilities management (FM) course and an international audience at its annual FM conference. Both events continue to provide a source of corporate members to the MIT-founded International Society of Facilities Executives (ISFE). This year also marked the third and last intensive summer program in FM for the Japanese Facilities Management Association (JFMA). Funded by JFMA, the course was jointly presented by OFMS and the School of Architecture and Planning.

KREON L. CYROS

Physical Plant Department

This year the department took particular pleasure in its substantial participation in preparations for the Inauguration of Dr. Charles Vest, fifteenth President of MIT. Both this special event and Commencement are times when all members of Physical Plant can take great pride and satisfaction in their individual and collective efforts.

The department has initiated publication of a newsletter describing some of its major activities, personal notes on departmental personnel, and other topics that are of general interest to the community. The newsletter will be published on a quarterly basis with an occasional special issue.

A brochure is being developed describing functions and services delivered by the department. "A Guide to Physical Plant Services" will be available to the community early next year and will contain a list of the services offered by Physical Plant.

All areas of the department are concentrating on "customer service" in their daily activities. In conjunction with a higher level of communication with the community, these efforts appear to be receiving recognition by members of the community.

Over the past year, the department continued to work closely with the staff of the Division of Comparative Medicine to identify problems and improve the overall operating environment of the animal care facilities on campus.

This year, air conditioning projects completed in the Main Group added approximately 70,000 square feet of newly air conditioned space. The chilled water distribution system kept pace and new central pumping facilities were installed in Building 4 along with high quality flow meters in Buildings 4, 13, and 66.

MANAGEMENT INFORMATION SYSTEMS

Development of the Physical Plant Management Information system continues. The Preventive Maintenance (PM) Module is now in production and PM tasks are now being conducted on line. The new Labor Module, which will track labor costs and integrate with the Institute's payroll system, is in the final stages of development. Work has begun on the Utility Distribution Module for distributing appropriate utilities costs to each facility.

COGENERATION PROJECT

The combined-cycle cogeneration project, which began in the spring of 1986, continued through the year. Major emphasis was on securing an air emissions permit. After a disappointing rejection by the Massachusetts Department of Environmental Protection (DEP) of the Institute's Environmental Impact Report, the program took a new direction using advanced combustion technology not previously available. This concept, which addressed the concerns of the DEP, has now been endorsed by them and all indications are that the permits will be issued.

WATER CONSERVATION

This year City water and sewer services cost the Institute over \$2 million, double what it cost in 1986. As the fastest growing budget item, the Institute can anticipate another increase of from 40 to 50 percent by the year 1995. However, perhaps as much as 25 percent of water use can be saved through conservation efforts. A survey to determine

the extent of conservation opportunities conducted this year identified several large projects, as well as a large list of smaller potential projects, that require further investigation.

REGULATORY AND CODE COMPLIANCE ISSUES

The need to comply with the current burgeoning City, State, and Federal environmental regulations demands a major commitment of departmental resources. Some examples of regulatory requirements are asbestos and PCB abatement, underground fuel and storage tank testing and inspection, boiler and incinerator stack effluent source registration, elimination of city water cross-connections, and sewer discharge monitoring and testing.

ELECTRIC SERVICE AND RELIABILITY

Due to three separate incidents of wide spread black-outs this year, the reliability of the joint Cambridge Electric Light Company (CELCo)/MIT primary distribution system was questioned. Analysis of the outages disclosed some significant concerns with the basic design and operating philosophy under which the campus is served by CELCo. After a series of meetings with management and engineering staffs on both sides, equipment changes and operating procedures which address the problem have been implemented.

All emergency power and lighting systems were reviewed during the year. Emergency generators have been put on a preventative maintenance program to increase reliability. This program proved beneficial during the power outages which occurred during the year.

ENERGY CONSERVATION/ELECTRIC REBATE PROGRAM

Phase I of the shared savings Electric Rebate Program concluded this year. Rebate payments to MIT of more than \$1.1 million and a reduction in use of 18 million kilowatt hours have been achieved. Following a delay in the implementation of Phase II, it was determined not to pursue further participation in this program due to the likelihood of proceeding with cogeneration for the campus. Physical Plant's interest in energy conservation remains strong, however, demonstrated by the installation of power factor correction equipment in several buildings not now served by the campus distribution system.

FACILITIES MAINTENANCE, CONSTRUCTION, AND RENOVATIONS

Large scale maintenance projects during the year have resulted in roof replacements on the lower sections of the Karl Taylor Compton Laboratory and Kresge Auditorium. Extensive repairs were made to the West Garage with repairs to both the Albany Street Garage and the East Garage scheduled for next year.

The President's House was extensively renovated with the installation of a new air conditioning system and improved handicapped accessibility. The heating, electrical, and fire/safety systems were all upgraded as well.

Lecture hall 2-390 was converted into two floors and a mezzanine level, providing 17 offices for graduate students and visiting faculty in the Department of Mathematics.

The Undergraduate Education Office was consolidated after completion of renovations to offices at the junction of Buildings 20-B and 20-C on the first floor.

Several capital projects were completed over the year. The new Rotch Library and the renovations to the existing library are the most notable.

Design work continued during the year on the new Biology Building which will be situated on Ames Street. The decision to add a second basement (32,000 square feet) will bring the total area to 244,000 square feet. Excavation is now underway and actual construction is expected to begin in October. Once construction is underway, the programming will begin for major renovations to Building 16 for occupancy by the Physics Department and changes to areas in Building 56 that will be vacated by Biology.

Work is continuing to prepare the former A. D. Little occupied building at 38 Memorial Drive (Building E56) for occupancy by the School of Management in September. The facility will house a state-of-the-art classroom, seminar rooms, faculty offices, research centers, and an executive briefing center.

HARMON E. BRAMMER

Planning Office

The Planning Office's efforts this year have been designed to prepare for the decade ahead. The research, analysis, and planning studies have addressed each of several key areas in specific ways.

An extensive inventory of potential capital projects, their projected costs, and their location on campus was completed and will be updated annually. It provides a comprehensive picture of those capital needs and their implications for land and financial resources for the next 10 to 15 years.

A major study of the Vassar Street area of the west campus has been completed. Primarily focused on new undergraduate residence locations, it also addresses issues of landscape, pedestrian and vehicular circulation, and service requirements in this highly-visible section of the campus. In addition, a land resource requirements analysis was prepared for the Real Estate Subcommittee of the Institute's Investment Committee.

In a separate but related effort, a study is underway to rationalize traffic patterns along the northern, southern, and western sections of the campus. This study will explore crucial access and circulation routes and will be used in cooperation with efforts undertaken on behalf of the University Park development project and in cooperation with the City of Cambridge to find reasonable solutions to this pressing community issue.

As part of the Institute's Master Landscape Plan, the Planning Office developed an electronic database of all plantings and landscaping materials in use at the Institute. This resource has now been transferred to the Grounds Section of Physical Plant as a reference for maintaining and enhancing the environment.

The renovation and refurbishment of existing classrooms enters the third year of a tenyear implementation plan. To assist the Schools of Management and Architecture and Planning in meeting future goals, studies of their space needs were prepared for senior management review.

The Planning Office continued its efforts to identify possible locations for student housing keeping in mind scale and quality and the physical, financial, and social implications for Institute policy and community life. Completion is expected in August of the renovation project of a property on Commonwealth Avenue, to be used as MIT's first sorority house (Alpha Phi) which will house up to 60 women.

As part of its commitment to the quality of life and improving access for all individuals, the office has continued to identify opportunities for improving handicapped access, to maintain both large-format and carry-around access maps, and to monitor compliance with federal, state, and local laws.

This year's *MIT Factbook* indicates that our total on-campus employees have increased by 153 to 8,068. At the same time, the number of faculty decreased by two to 986 or 12.2 percent of total employees, although the steady increase in the tenure rate continued, reaching 75.2 percent. The undergraduate student population also declined from last year, by 19, to a total of 4,276. The number of graduate and special students remained relatively stable at 5,260.

O. ROBERT SIMHA

Safety Office

The Legislature is again considering extensive reform of the Massachusetts Workers' Compensation Law. Initiated by employer groups around the state, the Safety Office has been actively participating in this effort.

This was our second year of self-insurance for Workers' Compensation. While the frequency of recordable injuries remained unchanged from last year, the number of lost work days increased. Those departments which aggressively implemented the Restricted Duty Program, however, experienced a significant decline.

EDUCATION AND TRAINING

Art projects and theater and stage productions represented major concerns this year. An "Art Review Form" was developed for use by students wanting to display art in public spaces at MIT. The Safety Office worked in conjunction with other departments to ensure that safety standards will be met.

The Safety Office participated in the Occupational Safety and Health administration (OSHA) Laboratory Standards program by reviewing all departmental programs and assisting in the training of Chemical Hygiene Officers.

Material Safety Data Sheets (MSDS) which are required by OSHA to be available in the workplace are now accessible via electronic mail from the MIT mainframe computer.

HAZARDOUS MATERIALS

Due to the new classification of such items as batteries, paints, chlorofluorocarbons, and copier chemicals as hazardous waste, it is expected that waste volumes will increase. All polychlorinated biphenol (PCB) transformers on campus have been taken out of service or retrofilled in accordance with EPA regulations. In addition, all known PCB capacitors have been disposed of. All PCB transformers and capacitors have also been taken out of service at Haystack and Bates.

All photographic dark rooms on campus were surveyed to ensure proper treatment and disposal of hazardous wastes.

FIRE PROTECTION

Fire protection systems have been improved at both Endicott House in Dedham and at the President's House.

There was one significant fire on campus this year, in Burton-Conner, when a fire was started by one of the residents. Fortunately there were no personal injuries and minimal property damage due to the activation of automatic sprinklers. This incident was the only fire that exceeded the \$5,000 insurance deductible.

SAFETY AUDITS

More departments are requesting safety audits as the level of safety awareness increases. This year the Center for Materials Science, Chemical Engineering, the Center for Space Research, and Plasma Fusion conducted safety audits.

Members of the Safety Office participated in a Design Review Committee which was established by Physical Plant to develop construction guidelines and check lists for design professionals.

PERSONNEL

Katie Blass passed the Certified Safety Professional examination and was promoted to Safety Officer.

JOHN M. FRESINA

VICE PRESIDENT AND TREASURER

INTRODUCTION

The Campaign for the future continued at a high level of activity during the year. There was an increased emphasis on solicitation of individual prospects to follow up on several years of cultivation and involvement of alumni and friends. The economic recession and the decline in the stock market early in the fiscal year caused some reduction or postponement in the expected Campaign commitments from individuals. Most of the adverse effect on the Campaign of these conditions was offset by very strong commitments from foundations and by continued commitments from corporations.

Gifts and pledges to the Campaign reached \$605.2 million, an increase of almost \$88 million during the year. Gifts of cash, securities and real estate recorded in the Campaign totaled \$92.4 million for the year, a decline of 10% from the previous year. Since gifts received exceeded the increase in the Campaign total, there was a decline of about \$4 million in outstanding pledges to be paid in the future. The outstanding pledges have been maintained at a high level for the past two and one-half years and now total \$113 million.

An important activity this year was the transition to a new team of senior officers and the introduction of the new President, Charles M. Vest, and the Provost, Mark S. Wrighton, to the friends of the Institute. The cooperation of the Alumni Association was important in this process and helped to strengthen our many ties with individuals, foundations and corporations. Both Dr. Vest and Dr. Wrighton traveled throughout the nation on behalf of MIT and also traveled abroad, including trips to Italy, Germany and France by Dr. Vest. Dr. Paul E. Gray moved from President to Chairman and continued his high level of activity on behalf of the Campaign. The success of this team and the other senior academic appointments provide considerable optimism for the coming year and beyond.

The planning for the final year of the Campaign was an important element of our Spring activities. The Advisory Group of the Corporation Development Committee and the other members of that organization, the Corporation and the Campaign volunteers provided useful input. Our final year will include significant efforts to solicit all prospects capable of meaningful Campaign commitments and to build a base for the post-Campaign period.

Resource Development is divided into three major areas by the source of gifts: Individual giving activities, Corporate Relations, and Foundation Relations. Individual giving activities include Major Gifts and the National Campaign Office, and major portions of the central activities relating to communications and prospect research (Campaign Systems). The Treasurer's Office and the Alumni Association all carry on important fundraising activities that are closely linked to Resource Development.

The Corporate fundraising activities are assigned to Corporate Relations which includes the staffs of both the Industrial Liaison Program and Corporate Development. Foundation Relations and Development Services includes both fundraising from foundations and school-based fundraising from all sources.

Resource Development professional staffing for the Campaign remained stable during the year with the addition of five newly hired staff, made up of two woman and three men including an Asian American who became the Director of the Industrial Liaison Program Japan Office on June 1. There were 19 promotions (13 women-68%, and one Black American male-5%), including five from support to staff positions. On January 1, 1991, D. Hugh Darden, Associate Treasurer, assumed the position of Acting Director of the National Campaign Office, following the resignation of Henry Barg. Also on January 1, Barbara Stowe assumed added responsibilities for Development Services and was promoted to Director of Foundation Relations and Development Services. Cordelia Foell was promoted to Director of Academic Development, supporting the fundraising activities of the Provost. John Jacoby moved from Associate Director of Development Services to Associate Director of Communications. Since the close of the fiscal year, Frederick Gross, Director of Corporate Development, has resigned and will be succeeded by Karl Koster, formerly Manager of Corporate Relations. Effective July 1, 1991, the management of the fundraising activities of the MIT Sloan School of Management were transferred from Resource Development to the School. We continue to seek qualified women and underrepresented minority candidates for all open positions.

PRIVATE SUPPORT

Private support for fiscal year 1991 totaled \$101.1 million, including the following: \$92.4 million in gifts, grants, and bequests, and \$8.7 million in support through membership in the Industrial Liaison Program. The total compares with \$111.1 million in 1990, \$86.9 million in 1989, \$91.9 million in 1988, and \$76.4 million in 1987. Gifts-in-kind for the past year (principally gifts of equipment) were valued at \$18.0 million and are not included in the gifts reported above.

Sources of gifts for fiscal year 1991 were: alumni, \$25.4 million; non-alumni friends, \$10.0 million; corporations, corporate foundations, and trade associations, \$37.3 million; foundations and charitable trusts, \$18.8 million; and others, \$0.9 million.

Donors designated expendable and endowed funds as follows: unrestricted, \$11.6 million; departments, \$39.2 million; faculty salaries, \$17.2 million; graduate student aid, \$8.5 million; undergraduate student aid, \$9.1 million; building construction funds, \$0.2 million; and other funds \$6.6 million.

Private support in 1991 increased the commitments raised for the Campaign to \$605.2 million, representing 86% of the \$700 million goal set for June 1992. By Campaign priority, commitments raised and percentage of goal achieved were the following: Endowment for Faculty Chairs, \$86.5 million (79%); Academic Programs, \$293.6

million (98%); Student Support, \$91.6 million (76%); New and Renovated Facilities, \$16.7 million (24%); and Unrestricted Gifts, \$97.4 million (97%). In addition, commitments totaling \$19.4 million are pending designation.

MAJOR GIFTS

The Office of Major Gifts, directed by H. E. (George) Ramonat, is responsible for the identification, cultivation, solicitation and stewardship of donors with the capacity to make a gift of \$500,000 or more to the Institute. It also manages the development process for donors who have relationships with the President, Provost, or the members of the Corporation Campaign Committee, regardless of their philanthropic capacity. In addition, the office is responsible for the development process for Campaign prospects in the New York Metropolitan area and Northern California, including San Francisco and Silicon Valley.

The Major Gifts research group prepared 49 solicitation plans, 16 of which represented re-solicitations and produced 107 cultivation plans, numerous prospect profiles, qualification reports and managed a number of prospect strategy sessions.

Major Gifts concentrated on prospects in the New York Metropolitan area capable of making gifts of \$50,000 or more to MIT. The New York Metro team continued its activities in New York City, Long Island, New Jersey and Southern Connecticut making calls to identify new prospects and managing cultivation events hosted by area volunteers. Particularly significant were a dinner hosted by Dale Schain Krouse featuring Dean Philip Khoury, a breakfast honoring President Vest hosted by John Castle and the second in a series of luncheons hosted by Barry Rein at which John Preston, Director of the MIT Technology Licensing Office, addressed issues of technology licensing.

In fiscal year 1991, a high rate of activity continued with particular emphasis on the solicitation and stewardship of major donors, and the introduction of the new senior officers of the Institute. The staff managed 114 solicitation and cultivation visits. In addition, 10 cultivation and stewardship events were held both on and off the campus attended by 52 prospects. Highlighting these events were the dedication of the Berenice Abbott Photography Lab representing Campaign gifts of Ronald Kurtz; the 20th annual Gilbert Winslow Scholars and Professors Luncheon with Mrs. Ruby Winslow Linn, Mr. Winslow's sister and donor to the fund; and a dinner reception honoring Mrs. Lee Abramowitz and the 29th Abramowitz Memorial Performance of Music. The objectives of stewardship events are to honor donors as well as effectively cultivate the honorees and other invited guests. The growth and importance of stewardship events is reflective of the need for high level, ongoing recognition of major donors as the Campaign enters its final year and the continued need to strengthen relationships with MIT's foremost supporters.

Principal Gifts activities were heightened with the increase in stewardship activities for major donors to the Campaign. Fifteen

principal gift donors were solicited or resolicited for major Campaign support, and five events were coordinated in recognition of major gifts made during the Campaign. As well as responsibilities for principal gifts and major gifts activities for Boston, the middle Atlantic states, and the mid-west, the Associate Director for Principal Gifts also coordinates development efforts for the Associate Provost for the Arts.

Major Gifts assumed responsibilities for all Northern California prospects with the assignment of a Senior District Director to this area in November 1990. Campaign-related events included dinners hosted by Robert Metcalfe, Vernon Altman, Hamid Moghadam and Gerald Burnett. Highlights of Northern California efforts include the first presidential trip to the area involving four volunteer hosted dinners, a luncheon and an alumni reception; and two dinners respectively introducing Provost Wrighton and Associate Provost Ellen Harris.

A renewed effort is being made to identify and begin to cultivate European alumni under the direction of the Assistant Dean for Resource Development in the School of Architecture and Planning, and the Director of Foundation Relations and Development Services. President Vest participated in six cultivation visits with key alumni in Paris in March.

The Major Gifts Office is also responsible for individual donor relations, preparing appreciation letters for the signature of the president and chairman for gifts and pledges of \$3,000 and above.

Personnel changes included the promotion of Glenn Billingsley from support staff to Development Officer for the Arts in October 1990; Lee-Ann Day assumed the half-time role of Assistant Dean for Resource Development in the School of Architecture and Planning on December 1, 1990 while continuing on a half-time basis in Major Gifts; Julie Eastman was promoted to Assistant Director for Donor Relations in December 1990.

NATIONAL CAMPAIGN OFFICE

Under the direction of Acting Director D. Hugh Darden, the National Campaign Office, working with Campaign volunteers, has continued to emphasize the cultivation and solicitation of prospects capable of making gifts in the range of \$50,000 to \$500,000. This year was marked by intensified and sharpened focus on solicitation, including campus visit attendees not already solicited. There were several small cultivational events held off campus and some special visits to campus by donors with high potential. Under the direction of D. Reid Weedon, Jr., some 264 volunteers on the National Campaign Committee continued to contribute importantly to the solicitation effort.

Beginning at mid-year, a major re-evaluation of potential donors in the Boston area was completed and, as a result of adjustments in staff appointments, it was possible to devote the efforts of an equivalent of three full-time District Directors to the Boston Campaign activity. These staff members, operating as a team,

greatly intensified necessary cultivation and solicitation. They were assisted by a group of active and retired faculty, along with other members of the administrative staff, in taking necessary action with respect to 233 top priority potential donors in the Boston area.

The Emma Rogers Society was formed in July 1990 to provide continuing interaction between the Institute and 2,200 alumni and faculty widows of record. Activities and projects included a dinner; symposia on campus; a travel network; and an Emma Rogers Society table at the Technology Day Luncheon. In Memoriam, a booklet listing those in whose memory gifts had been made in the previous year, was published and sent by the Society in November to all widows and donors of memorial gifts.

During the year, Joy Carrigan transferred to the Major Gifts Office; Michael Dempsey joined the staff as Senior District Director; and Carole Gunning was hired as Assistant to the Director with special responsibilities for office operations. In addition, Meredith Thomas was promoted to District Director II and Robert Arnold was promoted from Senior Research Analyst in the Office of Campaign Systems, to District Director I.

Sustaining Fellows and Special Events

Under the management of Cassandra Page, the Sustaining Fellows and Special Events office coordinated 16 events on campus and in other locations. Two events held in Palm Beach and Naples honored Florida Sustaining Fellows and featured Provost Wrighton as the speaker. All Sustaining Fellows were invited to President Vest's inauguration in May. Early in the year an updated Sustaining Fellows brochure and membership list was mailed to the more than 1000 members and in February, each Sustaining Fellow received Professor Paul Krugman's book, The Age of Diminished Expectations.

Campus Visit Program

During its fifth year of operation, the Campus Visit program, managed by Estelle Cashman, held seven campus visits, one in the summer, three in the fall and three in the spring, with 251 alumni, spouses and friends of MIT attending. In addition, a day-long program for the Phi Beta Epsilon Fraternity's Centennial On-Campus Visit was held in September. More than 150 MIT alumni and spouses attended this function, many of whom were considered prospects for the Campaign for the future.

The format for each Campus Visit was similar: an opening reception and dinner at the MIT Museum Thursday evening; a full day of informational programs on Friday followed by dinner hosted by the President, or other senior officer, and their wives; and breakfast Saturday morning. President and Mrs. Vest hosted their first Campus Visit in November 1990.

Since the Campus Visit program began in October 1986, 515 MIT alumni and friends (usually with spouse or guest) have attended thirty Campus Visits. By the end of fiscal 1991, some \$35 million in gifts

and pledges had been received from these Campus Visitors in response to solicitations made after their attendance. Two hundred and three MIT professors and teachers have presented 182 programs during the course of the visits. Approximately 600 students (an average of 20 students per visit) have participated in the programs and/or joined the visitors for meals.

OFFICE OF CAMPAIGN SYSTEMS

While continuing to respond to requests for research, production, and programming support from Resource Development staff, the Office of Campaign Systems, under the direction of Shelley Brown, this year developed several internal prospect identification programs. The programs included monitoring corporate mergers, acquisitions, and new public offerings; tracking alumni promotions and new appointments; identifying MIT-affiliated company founders.

As a result of these activities, over 50 new prospects were identified and brought to the attention of the field staff. The research also surfaced information that provided the impetus for congratulatory notes to almost 200 alumni recognizing their achievements. Among other research initiatives were: ongoing maintenance of an MIT Founders database; creation of a Memorial Funds/Donors database; and profiles of alumni and development activity in several European countries.

Most of the research effort was in response to more than 1200 information requests for prospect profiles used by Campaign field staff and volunteers. In addition, the office continued to administer the Campaign's Prospect Management System, which last year produced several new reports showing the solicitation status of active prospects.

Other key activities included production support for Campaign events and Campus visits and the management of all Campaign giving reports and analyses. The programming staff within Development Information Management Systems (DIMS) was responsible for producing 600 reports in response to requests made throughout Resource Development. The DIMS staff continued to help maintain the ADDS database, particularly, but not exclusively, those files owned by Resource Development.

Several members of the staff were promoted during the year, including Nancy Olt from Assistant Director to Associate Director, with responsibility for managing a staff of 10 research analysts; Mary Gulino to Assistant Director from Manager of Production and Systems Support; and Stephen Gilligan to Analyst/Programmer II. Two members of the research staff, Eric Liskin and Elisa Murray, were promoted from support to the administrative staff positions of Senior Research Analysts.

OFFICE OF FOUNDATION RELATIONS AND DEVELOPMENT SERVICES

Foundation Relations

The staff in Foundation Relations continued its efforts to raise funds for MIT's research and educational programs. Cash receipts

totaled \$18.8 million for the fiscal year, and commitments to the Campaign from foundations reached \$152 million. Major grants were received for the following: structural biology; energy research; a new program to study and improve U.S. industrial productivity and competitiveness; the Program in Science, Technology and Society; a study of the pharmaceutical industry; and fellowships in the Parsons Laboratory, the Department of Materials Science and Engineering, and the Department of Mechanical Engineering.

Director of Foundation Relations, Barbara Stowe, assumed responsibility for Development Services, and John Wilson, formerly with the Office of Corporate Development, joined the newly-merged group as Associate Director. Dr. Wilson manages the day-to-day activities of Development Services and oversees the research and professional staff. He works directly with faculty on fundraising initiatives and helps to coordinate development efforts for Institute-wide projects. Lisa Hiley's title changed from Assistant Director of Development Services to Assistant Director of Foundation Relations.

Development Services

The Office of Development Services, directed by Dr. Wilson, continued to work closely with the school development officers, faculty and the Office of the Provost, providing support for project management, the development of solicitation and cultivation strategies and stewardship programs. During the past year, the staff of three researchers and three assistant directors responded to over 200 requests for information on potential donors, and prepared over 40 proposals.

The staff's support of various initiatives during fiscal year 1991 was vital to the funding of key projects within each of the schools. For instance, within the School of Engineering, Development Services provided research and direction for solicitation efforts for several professorships and projects, including the Microsystems Technology Laboratory, the Apollo Program Professorship, the Parsons Laboratory, and the Hazardous Substances Program. Considerable effort was devoted to identifying present or potentially important Engineering alumni and facilitating communication between them and the School.

Within the School of Science, Development Services supported a variety of fundraising activities related to the construction of the new Biology Building, the Department of Chemistry, and the Center for Global Change Science in the Department of Earth, Atmospheric and Planetary Sciences.

Among the major Sloan School initiatives supported by the staff were the new Center for Entrepreneurship and the research program in international conflict management.

The School of Humanities and Social Science has focused on funding for the Paul A. Samuelson Chair in Economics, World Economy Laboratory, Chinese Language Program, Knight Science Journalism Program, and Defense and Arms Control Studies, and has been active

in identifying and cultivating alumni, corporate, and foundation prospects for ongoing support of the School and its faculty.

The School of Architecture and Planning prioritized funding for the Rotch Library expansion project, fellowships, and research support. Development Services worked on program development and event coordination for the ongoing series of Dean's Breakfasts to cultivate alumni. It also assisted in identifying firms that might be prospects for fellowship support, and in preparing cultivation and solicitation plans and proposals.

Stewardship projects included coordinating luncheons; reporting on scholarship, fellowship, and UROP funds; and preparing information for professorship inaugural events.

CORPORATE RELATIONS

Corporate Relations, under the direction of Eric Johnson, continued to integrate the Industrial Liaison Program functions with the fundraising efforts of Corporate Development. This has resulted in closer interactions with the faculty and departments, and more activity related to the priorities of the Institute. Corporate Relations staff are involved in helping to develop major funding initiatives related to telecommunications, the environment, and engineering education, as well as continuing efforts on Leaders for Manufacturing, and other programmatic initiatives.

The Industrial Liaison Program (ILP)

The ILP, headed by Thomas Moebus, director, ended the year with 238 member companies, including 28 new members, and record revenues of \$8.7 million. A survey of these members was conducted, which found that monitoring technology, gaining access to research, and building relations with faculty were the highest motivations for membership. For American firms, recruiting MIT students is a very important consideration. The ILP received very high scores for effectiveness from member companies. Based on the advice of the members, and with the cooperation of the faculty, faculty visits to company locations were significantly increased to 524. A new information base is being created which will eventually offer selected direct electronic access to members.

Corporate Development

Corporate cash receipts maintained the unprecedented increase of last year, finishing at \$37.3 million, 2% above the fiscal year 1990 results of \$36.4 million. Efforts were undertaken by the staff of Corporate Relations to stimulate new proposals in order to sustain these levels and that will be the primary focus of our fiscal year 1992 Corporate Development activity.

Promotions in Corporate Relations included the following: Karl Koster to Director of Corporate Development in August, 1991; Joseph Baclawski to Manager of Corporate Relations; Cynthia LuBien to Manager of Corporate Relations; Kenneth Goldman to Senior Liaison Officer; Lisa Bartolet to Administrative Assistant; Debra Thibodeau

to Faculty Travel Coordinator; and Christine Mleynek to Assistant Director for Research in Corporate Development. New appointments include Robert Malster to Industrial Liaison Officer and Ray Tsuchiyama to Director, MIT/ILP Japan Office. Beni Inouye will remain in the Japan Office in the role of Assistant Director of Far East Corporate Relations.

Kay Tamaribuchi and Christopher Dippel left MIT to take posts at other educational institutions; and Frederick Gross, who has served MIT for twelve years, most recently as Director of Corporate Development, is also leaving to take a position at the RAND Corporation.

NATIONAL BUSINESS COMMITTEE

Robert Hagopian, Director, continued and expanded efforts to develop new relations with corporations with emphasis on increasing Industrial Liaison Program membership on the part of North American companies. This activity is closely coordinated with the ILP's marketing efforts, targeting potential member companies which can be approached most effectively by National Business Committee members.

He continued responsibility for National Campaign activities throughout Canada and in Seattle, as well as assisting colleagues responsible for other areas.

In addition to coordinating Resource Development relationships with the Alumni/ae Association in the selection of volunteers for awards, committees and offices, he continued to oversee the internal processes by which alumni who are senior corporate executives are evaluated for Corporate Leadership Awards.

CORPORATION DEVELOPMENT COMMITTEE

The annual meeting of the Corporation Development Committee (CDC) was held in Cambridge on November 7, 1990. The meeting was opened by Chairman Gray, followed by remarks by President Vest and presentations by Vice President and Treasurer Glenn Strehle, Corporation Campaign Committee chairman Carl Mueller, National Campaign Committee chairman D. Reid Weedon, and Alumni Fund chairperson Karen Mathiasen. The deans of the five Schools then outlined the needs and current projects of each School. Luncheon featured the presentation of the Dalton Bowl to Peter Saint Germain for his ongoing volunteer leadership and dedication on behalf of MIT.

In an effort to evaluate MIT's present and future fundraising efforts and the role of the CDC, a 20 member CDC Advisory Group gathered for a retreat on June 3-4, 1991 at the Wellesley College Club. Chairman Gray and President Vest addressed the opening dinner on the importance of private support for MIT and requested that the Advisory Group assist in the evaluation of MIT's fundraising efforts. Following a presentation by Provost Wrighton at breakfast, the group was divided into sub-groups and asked to evaluate various aspects of the Campaign for the future: the role of the volunteer; Resource Development activity following the Campaign; and the future

role of the CDC in MIT's development efforts. At lunch, each group leader made a summary presentation. The CDC annual meeting and CDC Advisory Group retreat were planned and coordinated by staff members of the CDC Working Group, headed by H. E. (George) Ramonat, Executive Officer of the CDC.

COMMUNICATIONS

The Office of Communications, directed by Elizabeth Harding, is responsible for the coordination, production, and distribution of all Campaign publications. In this past year the office created two major new brochures, Professorships at MIT and Arts at MIT, both outlining priorities of the Campaign for the future.

Spectrum, the Campaign's 16-page newspaper, continued as an important project and an effective medium for showcasing the accomplishments of the MIT community, including profiles of alumni/ae. Two newsletters also remained a focus: one aimed at parents of undergraduates and another at Campaign volunteers working through Resource Development and the Alumni/ae Fund. Staff assisted in the preparation of brochures and a newsletter for the Emma Rogers Society.

The office added 10 new "donor profiles" to a series of planned giving testimonials that appear in Technology Review and once again produced MIT Facts, a 44-page booklet presenting a brief, general overview of the Institute.

Glenn P. Strehle

ALUMNI ASSOCIATION

This past year was one of incredible global change. Those changes and their attendant uncertainty took its toll on our staff, volunteers, and results. Yet in spite of all the external and internal turmoil for many of us, the Association of Alumni and Alumnae of MIT continued its substantial strong supportive efforts on behalf of the Institute and its alumni and alumnae. Our fundraising efforts in support of the *Campaign for the future* achieved our second most successful year. MIT ProNet serviced over 1,000 alumni and alumnae with job search opportunities. Alumni and alumnae turned out in record numbers to hear about the wonders of molecular biology at Technology Day, in 15 cities to hear about what could be done about failing pre-college education, and in black tie in Boston to welcome MIT's new President, Charles M. Vest. Finally, over 500 alumni and alumnae attended his inauguration, which included among other Institute functions a very successful reception for alumni and alumnae guests hosted by the Association.

Our volunteer leadership set even higher standards of commitment and collaboration led by Christian J. Matthew '43 and his most supportive spouse Marjorie. President Matthew traveled widely visiting alumni and alumnae throughout the world, meeting with alumni clubs in Pittsburgh, Salt Lake City, Albuquerque, Miami, Palm Beach, Tampa Bay, London, Zurich, and Athens. He was on campus on a regular basis from his home in California and became an integral part of the Association leadership. He asked the hard questions and did everything one could ask of a volunteer leader and more. He was ably aided by a strong Board of Directors, an able Alumni Fund Chair in Karen Mathiasen GM '72, and a very dedicated *Technology Review* chairman in Edward T. Thompson '49. Two members of the Board of Directors resigned. Vice President Vito A. Caravito '62 moved to Luxembourg; Robert H. Campbell SL '78, recently made CEO of his company, found his time increasingly devoted to professional interests.

We owe thanks to over 4,800 volunteers and countless others who support MIT and the Association's extensive volunteer activities.

ALUMNI ACTIVITIES

This was a year of great challenge and much success for the Alumni Activities group. Under the outstanding leadership of President Matthew, the panoply of volunteer activities sponsored by the Association continued to increase in number and improve in quality of content and in relevance to issues about which MIT people care deeply. The resultant increase in attendance provides a solid indication of the willingness of MIT's alumni and alumnae of continue their involvement with the Institute after graduation.

In this difficult year, which included preparation for war and war itself, combined with a sluggish economy and recession, the Alumni Fund, led by Chair Mathiasen, displayed remarkable resilience with gifts of \$15.1 million received from 28,145 alumni and alumnae donors. The dollar total is the second largest in history and follows a most remarkable year in which total gifts were swelled by the substantial impact of the Koch Challenge. The 28,145 contributors exceeds slightly the number of donors in FY '90. Of special note is the 5% increase in the number of graduate alumni and alumnae contributions.

As the *Campaign for the future* continues, the Alumni Fund has credited a total of \$88.1 million in cash receipts -- with an additional \$11.8 million recorded in pledges -- toward the overall *Campaign* goal of \$700 million.

ALUMNI FUND VISIT PROGRAM

Now in its fourth year, the Alumni Fund Visit Program was initiated in conjunction with MIT's *Campaign for the future* to seek support from alumni/ae who would not otherwise be personally solicited during the *Campaign*. Since the program's inception, in response to visits from fellow graduates, nearly 1,100 alumni and alumnae have contributed more than \$3.6 million toward the *Campaign*.

During the 1990-91 Fund year, there were 14 programs throughout the United States and four in Europe in which nearly 130 volunteer alumni and alumnae solicitors contacted 451 prospects and raised nearly \$700,000, exclusive of corporate matching gifts.

In the process, a new cadre of some 400 alumni and alumnae have been recruited and trained in solicitation techniques, which will be of great benefit in future campaigns.

TELETHON PROGRAM

An extensive number of alumni, alumnae, and student volunteers contributed to another successful year of telethons, which produced pledges totalling over \$917,000 from nearly 70% of the alumni and alumnae contacted. Over 17,500 alumni and alumnae, nearly 25% of the active alumni body, were reached during telethons held on campus and in 18 cities throughout the country. In addition to these highlights, the paid caller program produced pledges in excess of \$10,800 with 15 MIT students contacting 1,600 alumni and alumnae during a three week period.

During the 1990-91 year, regional phone solicitation efforts cracked the 200 caller barrier with 203 volunteers contacting 3,442 alumni and alumnae in 19 locations around the country. Overall, this undertaking raised a remarkable sum of \$328,083, up 40% over last year.

REGIONAL PROGRAMS

Regional club programs are the glue that keep alumni and alumnae in touch with each other and the Institute. There are over 70 active clubs around the world (42 in the United States), which hold over 500 meetings annually. Some of the larger clubs, including the MIT Club of Northern California, have more than 60 events in a single year with activities ranging from bike hikes to museum tours, from faculty talks to wine tastings, the common bond being support of MIT.

Notable highlights of the past year included the formation of a young alumni group in New York focused on alumni and alumnae of the ten most recent classes; receptions and dinners to welcome President Charles M. Vest held in Northern California, Washington, DC, and Boston; and presentations in 15 cities on the topic of scientific literacy in America, most of which featured Professor Ronald Latanision, Director of the MIT Materials Processing Center. A special feature of this year's regional programs was the extensive travel of President Matthew, who visited 22 MIT club gatherings in the United States and Europe.

CLASS PROGRAMS

Class reunion activity is the most visible result of the considerable volunteer effort made on behalf of MIT by nearly 750 class officers and committee members. This year over 1,600 alumni, alumnae, and guests from twelve classes celebrated fifth year reunions in June with attendance exceeding staff projections by 22%; 5th and 10th year attendance was over projections by 48%. Over 130 alumni and guests attended the three-day Cardinal & Gray Society reunion. Two classes will hold reunions in the fall of 1991.

Ten classes presented reunion gifts for a total gift of \$21.8 million. Gifts from the 50th reunion Class of 1941 reached \$5.3 million including \$244,000 in the Fund for the Impact of Science and Technology on Public Policy. The Class of 1951 raised gifts of \$4.6 million including \$690,000 for the Class of 1951 Fund of Excellence in Education aided by a challenge grant from the Grayce B. Kerr Foundation. The Class of 1966 gift of \$1.3 million was raised by a record-breaking participation of 77% of the class.

Other class gifts presented included: Class of 1926 65th reunion, \$6.4 million (third largest class gift ever received by MIT); Class of 1931 60th reunion, \$2.9 million; Class of 1956 35th reunion, \$340,000; Class of 1961 30th reunion, \$658,500; Class of 1976 15th reunion, \$110,000 (a record-breaking gift); Class of 1981 10th reunion, \$46,000; Class of 1986 5th reunion, \$28,000; Class of 1991 Senior Gift and pledges, \$38,000 for a fund to encourage MIT students to choose teaching as a career. These gifts include, for the first time, gifts from the 30th and 35th reunion classes.

Class giving campaigns in non-reunion classes were conducted by 68 class agents who acknowledged many of the 18,774 gifts made to the Alumni Fund by undergraduate alumni and alumnae sent their annual letters encouraging class members to participate in the Fund. Continuing their record of excellence, the Class of 1948 gift of \$483,000 was the largest non-reunion class gift in the Alumni Fund; 52 classes achieved or exceeded the Alumni Fund median gift goal of \$100; the class of 1935 had the highest participation rate with 66% of its members making gifts in the 1991 Fund.

Key to the continuing success of class programs is the program of activities conducted with undergraduate students. This year, the Association has launched in a pilot effort the Student Alumni/ae Council (SAC) to foster alumni and alumnae and student interaction and to acquaint students with Association programs. A student telethon volunteer committee helped recruit 373 student callers for a revitalized student telethon

program. Ten "student ambassadors" assisted alumni and alumnae during Alumni Week. In addition to the 254 students who contributed to the Senior Gift, 234 freshmen and 19 alumni/ae and 37 faculty and staff attended the Freshman Banquet for a total of 290 attendees; 551 seniors and 76 alumni participated in Senior Dinners, hosted by President and Mrs. Vest; 1,425 students, an increase of 57.5% over last year, enjoyed the Finals Lounge sponsored by the Association in the Bush Room.

ALUMNI WEEK/TECHNOLOGY DAY

In addition to providing support for class activities, from June 5-9, 1991, the Association sponsored a full program of Alumni Week activities for the more than 2,400 returning alumni and alumnae. General alumni programming including MIT Night at the Pops, attended by 2,000 MIT supporters, the Memorial Service in the MIT Chapel, the annual Technology Day Program and luncheon, and Alumni Barbecue and Games on Saturday, tours of Boston, a young alumni gala event on Saturday evening, and special activities for Cardinal & Gray alumni and alumnae. The weekend also included reunion activity for Sloan School and Biology Department alumni and alumnae. General alumni and alumnae participation continues to grow along with the growth of reunion class participation. This year general alumni participation exceeded 30% of all Alumni Week participants.

The Technology Day program was organized by the Biology Department under the guidance of the Association Technology Day Committee, chaired by George Clifford '48. The popular topic -- "Sex, Drugs, Genes & Obesity: The Impact of Molecular Biology on Your Health" -- was presented in a morning symposium and afternoon workshops conducted by 21 Biology Department faculty and MIT staff members. The symposium was led by Professor Harvey Lodish, moderator; Professor Eric S. Lander, DPhil, Associate Professor of Biology; Professor Robert D. Rosenberg, MD, PhD, LI '69, Professor of Medicine and Biology; Professor Herman Eisen, MD, Professor Emeritus of Biology, Professor of Immunology; and Professor Robert A. Wienberg PhD '64, Professor of Biology.

ALUMNI/AE LEADERSHIP CONFERENCE

The 1990 Alumni/ae Leadership Conference, held on Saturday, September 15, was attended by close to 400 alumni and alumnae leaders and their guests. During the day-long program, these volunteers were greeted by MIT President Paul E. Gray '54 as well as then President-elect Vest. Association President Matthew also greeted the attendees and presided over the annual awards luncheon, at which 23 alumni and alumnae were recognized for their outstanding service to the Institute and four exceptional alumni organizations were presented with Presidential Citations.

Scientific literacy in America was the theme for both the morning and afternoon sessions. An overview of the *MIT Science and Engineering Program for High School Teachers* was presented by Professor Ronald Latanision, Director of the Materials Processing Center, and a panel discussion followed featuring Avi Ornstein '71 and Charles Gliniewicz '67, both science teachers in New England public schools. During the annual meeting of the Association of Alumni and Alumnae of MIT, reports were presented by President Matthew and Chair Mathiasen. Following the annual meeting, a volunteer briefing completed the morning program, with presentations by Professor Frank Perkins '55, Dean of the Graduate School and Professor of Civil Engineering; Glenn P. Strehle '58, Vice President and Treasurer; Ellen Harris, Associate Provost for the Arts; and Kenneth Smith '58, Associate Provost for Research.

The afternoon program, which consisted of three concurrent sessions, was introduced by Professor Latanision. Attendees were invited to participate in *Community Involvement*, a panel discussion moderated by Bonny Kellermann '72 and including Susan Kannenberg '61, Peter Richardson '48, Margaret Daniels Tyler, and Emily V. Wade '45; *Educating the Work Force for a More Productive America*, presented by Suzanne Berger, Head of the Department of Political Science and Member of the MIT Commission on Industrial Productivity; and *National Issues and National Priorities*, presented by Professor Ronald Parker EE '63, Director of the Plasma Fusion Center, and Professor Latanision.

GRADUATE ALUMNI PROGRAM

Giving from graduate alumni and alumnae showed a 5% increase in donors and close to \$3 million dollars in gifts to the Annual Fund. Fundraising strategies included letters from department heads, department telethons, and a class agent pilot with the Sloan School. Increased effort to capture past donors through a more targeted letter from Dean Perkins and active participation in the spring telethon kept our conversion rate high.

Members of the Graduate Alumni Ad Hoc Committee -- Albert Bottoms MT '62, Lois Champy AR '71, Marylynn Gentry CP '88, Leslie Hruby GM '73, Charles Kolb, Jr. '67 CM, Frank Perkins '55 CE, David Steel PH '92, Emily L. Wick CM '51, and Arthur Winston PH '54 -- have focused their attention on ways to keep graduate alumni and alumnae connected to MIT and the Association and fundraising strategies.

Relational activity focused on building partnerships with departments by hosting events and strengthening graduate alumni involvement in current Association activities. Three events that helped forge these partnerships were a reception with the Department of Architecture and Planning at the American Institute of Architects Conference in Washington, a Biology Department reception and dinner in conjunction with Technology Day, and the inclusion of Sloan School alumni and alumnae in regions where Dean Lester Thurow was invited as a speaker.

PARENTS PROGRAM

The second MIT Family Weekend was attended by 1,800 parents and students, an increase of nearly 40% over attendance in the first year of the program. The Parents Fund, in its second year, also experienced growth, receiving 276 gifts from non-alumni parent donors, and reporting gifts of \$603,000 from all MIT parents. Of this total, \$127,000 was contributed by some 280 non-alumni parents, a dollar increase of 17%. The program newsletter, *Parents News*, was sent three times this year to the 5,000 families on our new database. A special summer edition was sent to parents of incoming freshmen. The program, conducted in collaboration with the Office of the Dean of Student Affairs and the Office of Resource Development, is managed by the Association staff.

YOUNG ALUMNI PROGRAM

The Association has continued to emphasize the significance of encouraging active involvement of its most recently graduated alumni and alumnae. This year a wide variety of activities were offered by the Association and MIT clubs across the country. In the final year of a pilot project, the Boston-area Young Alumni Steering Committee, comprised of both undergraduate and graduate members, planned and organized four events attended by over 300 local young alumni and alumnae, an increase of 100 attendees over last year. These events ranged from an Independence Day boat cruise to an extremely popular young alumni entrepreneur workshop (which drew waiting-list attendance). Undergraduate young alumni also showed increased financial support of the Institute, with gifts totaling over \$330,000 -- nearly \$24,000 more than in the previous year, a 7% increase. The Association young alumni newsletter, *The Intelligencer*, was mailed in the fall and spring to local Boston young alumni and alumnae and to all undergraduate and graduate volunteers, about 5,500 recent graduates. In addition, the Class of 1990 received its *Passport to MIT in the Real World*; return cards were received from 115 members of the class -- some from as far away as Japan and Taiwan -- expressing an interest in becoming involved in MIT clubs and as MIT volunteers.

SPECIAL PROGRAMS

Association of MIT Alumnae (AMITA)

The AMITA/UROP Oral History Project in which undergraduate students are paired with MIT alumnae to conduct oral history interviews continued to enjoy moral and financial support. The endowment fund currently totals \$39,000. Other highlights of the year included publication of a quarterly newsletter, the annual meeting at the President's House with guest speaker President Vest, and the annual presentation of the AMITA Senior Academic Awards.

Black Alumni of MIT (BAMIT)

To date, the Ronald E. McNair '77 Scholarship Endowment Fund totals \$70,000 and has benefitted two MIT minority students. The annual BAMIT National Meeting focused on "The Role of the Media in Shaping Racial Stereotypes and Perceptions." The annual exit reception for minority students with guest speaker Dr. Walter E. Massey, director of the National Science Foundation. BAMIT also hosted a special reunion luncheon attended by 20 minority alumni, alumnae, and guests.

Boston Seminar Series

Over 240 people subscribed for the 1990-91 Boston Seminar Series entitled *History in the Making*. An additional 60 people attended only once, totaling 300 attendees for the entire series. Mr. Winston chaired the series for his third and final year. Guest speakers included Dr. William Quandt PO '68, Senior Fellow of the

Brookings Institute; Dr. Hans Decker, President, Siemens Corporation; Dr. Yolanda Henderson, Economist, Federal Reserve Bank of Boston; Dr. Graham Allison, Professor of Government, former dean of the John F. Kennedy School of Government; Dr. William Griffith, Ford Professor of Political Science, former senior advisor to the Ambassador, US Embassy, Bonn; and Hon. Rita Klimova, Czechoslovakian Ambassador to the United States.

ALUMNI ACTIVITIES STAFF

Staff changes during the year included the following promotions: Joseph P. Recchio, associate director; Cathy Hatfield Brown, coordinator, major reunion giving; Christine G. Foglia, coordinator, reunions and special events; and Lore A. Greene, coordinator for graduate alumni/ae programs. New staff members include: Kathryn Battillo, program director, graduate alumni/ae programs; David F.A. Walker, regional director for the New York area and director of the MIT New York Center; and Emily Berkowitz, coordinator, student programs. The following individuals resigned: Barbara M. Peterson, program director for student and parents programs; Marcia Hartley, manager of the parents program; and Jane Grussing, coordinator of graduate alumni/ae programs.

Despite the turmoil caused by staff changes and the impact of the Gulf War and the economy on so many individual alumni and alumnae, this was a very good year for Alumni Activities. Staff continue to improve their level of support to volunteers and to stimulate new program initiatives. As the *Campaign for the future* enters its final year, all staff efforts will have a primary focus on its success, with planning continuing toward the post-*Campaign* period.

ALUMNI ASSOCIATION AWARDS

Bronze Beaver Awards

Noel Bartlett '60, Allen Latham, Jr. '30, Jean Pierre Gouyet EE '57, Priscilla Gray HM, Alessandro Ovi NU '71, Harris Weinstein '56.

Harold E. Lobdell '17 Distinguished Service Awards

Donald Cunningham '26, Sharon Lowenheim '79, Allan Gottlieb '67, Tyler Marcy '40, Hyun-A Park '83, Stephen Stuntz '67, Abraham Woolf '28.

George B. Morgan '20 Award

Richard Fossett '33, Edwin Miller '50, George Piness '49, Donald Schlatter '51, E.J. Schickli '50, Ernest Upton '43.

Henry B. Kane '24 Award

H. Kent Bowen ML '71, Edward Linde '62, Karl Miller GM '63, Jerry McAfee CH '40.

Presidential Citation Award

MIT Club of Paris, MIT Club of Singapore, MIT Club of Washington, DC; Silicon Valley Alumni Fund Visit Program.

Honorary Membership

George Thorn, Robert M. Solow, Margaret McDermott, Robert D. Blake.

TECHNOLOGY REVIEW

Total circulation of *Technology Review* continues to grow and this year topped 90,000. The number of outside paid subscribers now exceeds the number of alumni readers, with the breakdown roughly 50,000 and 40,000. The cost of acquiring paid subscribers remains low. The ongoing recession, however, coupled with the Persian Gulf War, took its toll in advertising sales throughout the industry, and the Review's experience was no exception. The magazine reduced expenses where possible to offset the advertising shortfall.

After nine years at the magazine, editor-in-chief Jonathan Schlefer resigned to write the book he never found time for and to enter the doctoral program in the Institute's Political Science Department. Efforts to finalize the redesign of the MIT pages, begun in the past year, await the new editor. The Alumni Association Board of

Directors approved funds for higher-quality paper in the section. The magazine has also begun a program to distribute copies to Institute faculty members.

Technology Review was awarded the 1991 *Magazine Week* Publishing Excellence Award in the science and technology category, the decision based on its ability to maintain the "highest standards in definition, recognition, and achievement of editorial mission." *The New York Times* has begun to syndicate the Review's articles to all newspapers nationally and periodicals abroad. A French edition of the magazine expects to begin publishing soon, joining the Italian edition and reprints in the Japanese magazine *B-ing*.

ALUMNI INFORMATION MANAGEMENT

Information Management accomplished two major goals: reduction of turn-around time for ADHOC programming requests and improvement of the data entry group's efficiency.

Mark Jacobs developed a state-of-the-art, on-line job submittal screen. Macintosh users no longer need to fill out forms for simple programming requests, such as labels, lists, and telephone directories. The users simply fill in their choices and press a submittal key. The job is then sent to the mainframe machine for FIFO processing. Lists are usually ready within 30 minutes after the job has finished running.

The data entry group's productivity and efficiency have improved immensely thanks to new supervisor John Quinlan, who focused his attention on getting the entire staff cross-trained on every job within the office. Gifts and address changes are now processed in the morning so that accurate lists and labels can be processed at night. As a result, the need for temporary help and overtime has been greatly reduced.

ADMINISTRATIVE SERVICES

Administrative Services expanded operations to include two new services: Macintosh consulting for the Association and the newly acquired Association Travel Program, formerly operated by the Quarter Century Club. The Association has progressed to the point that all word processing, spreadsheets, database applications and electronic mail are handled via a network of Macintosh computers that connect to the IBM mainframe. Services provided to clubs and classes include producing newsletters and class directories and providing them with reports, all via Macintosh. Our size and complexity is such that it became necessary to hire an individual who could assist staff with problems, train staff members on the proper use of varying software programs, and keep abreast of technology. This program has been successful addition to the range of internal services provided to the staff of the Association.

The travel program of the Quarter Century Club was transferred to the Association on January 1, 1991, when it was determined that most of the participants in the program were already alumni and alumnae. The program has been running successfully since then, with more than 200 passengers traveling to such destinations as Russia, Antarctica, and Papua New Guinea. The most significant change in the program will be the addition of a continuing education component and involvement of faculty lecturers on trips. For Fiscal Year 1992, we anticipate a higher number of alumni participating in over 30 trips. Ann Brazier, formerly of the Quarter Century Club staff, continues to manage the Travel Program for the Association.

WILLIAM J. HECHT '61