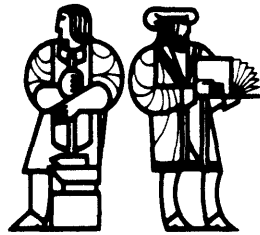

Massachusetts Institute of Technology



Reports to the President

1989-1990

Massachusetts Institute of Technology



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1989–1990

Reports for this book were submitted for publication in camera-ready form by MIT departments, laboratories, and centers.

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PRESIDENT

It has been an extraordinary year. In Eastern Europe and the Soviet Union, the political order underwent changes that not only caught the world by surprise, but also seem to be as deep as they are far-reaching. In South Africa, the government and the people have begun, in the midst of tragic turmoil, to take some steps that could lead to the end of apartheid and to the enfranchisement of the majority. In the Arab world, a brutal act of aggression has changed fundamentally the order of things: a change whose consequences will be far reaching and quite beyond estimation. In this country, people, and young people especially, once again raised the banners of political action for human rights -- for women, gays, people of color, and people with AIDS. And we, and neighbors around the globe, began to see the planet as our mutual home, one in drastic need of repair and exacting maintenance.

At MIT, the impact of these issues came right in, as it should. This place, much more than most, has to be of the world and therefore must take explicit recognition of these profound changes on the world scene. It has been our tradition to do so. Indeed, it is our mission to do so.

This year, as I reflect on the ten years of my presidency, I do so against the background of this turbulent period. Further, if I were to take the present moment as a predictor of the next decade, I would say that increasingly we will see politics, economics, and environmental issues at virtually any point on the globe bearing in significantly on other lands and other peoples. And I would say that MIT will be in the thick of things -- for that is what we are all about.

At the time of my inaugural, I outlined what I saw to be the major challenge for MIT in the 1980s -- and that was to forge educational and research programs that anticipated and responded to the social, political, and economic conditions of the coming years and, indeed, the coming century. Meeting that challenge, I said, required that we both preserve MIT's historic intellectual focus, with its insistence on excellence, and also transform our programs to meet the needs of the future.

The Elements of Excellence

Ten years later, I would say that the elements of excellence remain the same. These elements begin, of course, with a remarkable faculty and an extraordinary group of students. We are a culture that recognizes and rewards high achievement and, what is more expects it. Accordingly, we do our utmost to provide the setting, the resources, and the encouragement for all associated with MIT to do their best and to be their best. And they do: for a creative, entrepreneurial spirit permeates this place, as does a sense that what happens at MIT makes a difference in the world.

These values and conditions must be preserved; they are our bedrock. But it is not easy to maintain excellence in this time of uncertain resources for research, of diminished federal aid to needy students, and of growing public concern and skepticism about the costs, the benefits, and even the values of private higher education.

First among the challenges to sustaining excellence are those things intimately connected to attracting and keeping the best faculty. Many of the faculty who came to MIT and sister institutions in the period of rapid growth following World War II are, or soon will be, retiring. We and other universities will be seeking their successors at a time when fewer people are preparing for faculty careers than are needed to meet the future demand. Accordingly, our ability to continue to attract world-class faculty will depend in the first instance on our ability to be competitive in salaries. It will depend relatedly on our ability to recognize the constraints and the difficulties posed by dual careers, and, quite possibly, it will depend on our ability to help faculty find and afford housing in the high-cost Boston market. Finally, and ultimately, it will depend on our ability to provide an environment in which education and research can proceed with maximum vigor and effectiveness.

Second, and coupled very importantly to the quality of the faculty, are those issues related to attracting the very best students and to providing them with both the education and the support outside the classroom and laboratory -- housing, counseling, health services, and opportunities for relaxation and recreation -- that will insure their success. Above all, we must provide adequate financial aid. Nearly 2,500 -- some 57 percent -- of our undergraduates, received financial assistance from the Institute or from other sources this past year. In 1990-91, with the price of tuition, room and board at \$20,700, the average need for those students will be \$15,500 per year. This need, which includes self-help, will be met from a variety of sources, including increasing amounts from the Institute, from its alumni and alumnae, and from friends.

In regard to student aid, I would note in particular two significant and continuing trends during the past decade. The first is the decline in the federal share of the scholarship grants awarded to MIT undergraduates. In 1980-81 that share was 32 percent; by 1989-90 it had shrunk to less than 13 percent. The second is the increase over the past decade in the Institute's own annual commitment of unrestricted funds -- that is, funds in addition to those provided from the endowment -- that were allocated to undergraduate scholarships. These increased from \$1.5 million in 1980-81 to \$9.6 million in 1989-90.

Clearly, financial aid for our undergraduates, and our determination to raise it from the private sector, simply must remain a priority if we are to bring to MIT the very best young men and women of each generation.

In regard to graduate students, our ability to attract outstanding young men and women depends equally critically on the availability of financial support in the form of research

assistantships, teaching assistantships, fellowships and traineeships. In the last four decades much of this support has been provided through programs of the federal government which recognized explicitly the importance of graduate education to our national and global well-being. Unfortunately, that federal mandate has weakened to a distressing degree. For example, during the twenty-year period from 1969 to 1989 federally funded graduate fellowships and traineeships declined drastically -- from a peak of about 60,000 to fewer than 14,000. That massive decrease was only partially offset by a modest increase in the availability of research assistantships. In light of that pattern, it is hardly surprising that the number of U.S. citizens pursuing doctoral level education in engineering and the physical sciences declined markedly during this period, to the great detriment of the country's economic competitiveness and of other national goals.

Despite these changes in federal support, MIT's own graduate programs have remained strong. During the past academic year (excluding the summer), MIT generated or processed nearly \$85 million of graduate student support. But more than two-thirds of this amount was in the form of assistantships, with less than 9 percent coming as federal fellowships and traineeships. These latter types of support enable graduate students to take the necessary time to focus their academic interests before choosing a thesis topic, something not so easily done when one's support is coming from a specific research grant. Obviously, a decreased dependence on research funding, coupled with an attendant increase in fellowship support, could add significantly to the quality of student and faculty life and help ensure the continued excellence of graduate education at MIT.

Students and faculty do represent, then, the two elements of excellence that combine to make the fundamental excellence that is MIT. We cannot have one without the other, and if we don't have both we will have neither. It is often said that good students come here because of the opportunity to be taught and to work with our remarkable faculty, and that is surely true. But it is equally true that superlative faculty choose to come here because of the opportunity to interact daily with students of such outstanding quality as MIT's. These are the two indispensable determinants of the Institute's future. Because of them, I finish my term with the abiding conviction that there is no other place in the United States, indeed no other place in the world, better able than MIT to develop and sustain excellence.

Institutional Challenge and Renewal

And what of those things that ten years ago I felt needed to be changed? My agenda for institutional renewal then included the need, as I saw it, to:

- Rededicate science and technology as socially powerful activities

- Pay renewed attention to the pace, coherence, and intellectual impact of undergraduate education
- Improve the human environment and sense of community of MIT.

At the time, with the five-year *Leadership Campaign* coming to a successful conclusion just three months before my term began, I also naively deluded myself into thinking that I would be the president who held office between major fundraising campaigns. It was not to be, and fundraising became a major challenge: not only with the launching of the *Campaign for the future*, but also with the recognition that fundraising in private universities has of necessity become an ongoing, intensive enterprise involving the faculty and senior officers as well as a professional development staff and a large core of dedicated volunteers.

Rededicating Science and Technology as Socially Powerful Activities

At my inaugural in September of 1980 I stressed, as I looked ahead, that science and technology should be rededicated “as socially powerful activities”, that they might serve the nation and the world even more effectively. In the past decade, in addition to the many basic advances achieved throughout the Institute, we have seen a special strengthening of interest and activity in the MIT tradition of socially useful education and research. Over the decade there have been, for example, a number of major initiatives focussed on economic competitiveness, including in particular the landmark study by the MIT Commission on Industrial Productivity, which was reported in the widely acclaimed book *Made in America: Regaining the Productive Edge*.

The Schools of Engineering and of Management, to cite a related example, recently graduated the first students in their collaborative Leaders for Manufacturing program, which is designed to produce for U.S. industry a new generation of skilled managers with strong engineering backgrounds. These two schools are collaborating also in developing a New Products Program, which is intended to contribute to the understanding of successful product design and to work directly with industry to educate students in the fundamentals needed by industrial product teams.

Throughout the decade there has been also growing interest and activity in the environment and in waste control and management. One example, with a focus on research, is the interdisciplinary MIT Program on Hazardous Substances Management. Another, with a focus on education, is the curriculum in environmental engineering sciences that has been developed by the faculty in civil engineering.

There have been interesting initiatives in areas outside our activities in engineering and science as well. These include, just by way of example, the new degree program in real estate development, and additional support for our program for professional science

writers, which is intended to strengthen their ability to explain developments in science and engineering to the public. There is also an expanding interest at MIT in science education at elementary and high school levels, as evidenced by increasing faculty and student activities in local area schools. These range from summer seminars for high school teachers run by MIT faculty to student tutorials designed to explain and demonstrate scientific principles.

There is also at MIT a variety of new programs of international dimensions. Just one recent example is the interdisciplinary Center for Global Change Science, which focuses on the scientific questions, such as stratospheric ozone levels, involved in predicting possible changes in global environment. There are many other programs and activities that grow out of the international character of MIT. The Institute has always been such, of course, and one need spend only a few days here or watch the graduates as they receive their degrees to understand that our student body, in particular, is an international community. This past year, in fact, more than 2,000 of our students, over one-fifth of the whole, were citizens of other countries. And more than 1,100 international scholars from sixty-three countries visited -- and these are only the formally recorded visits -- virtually every department, laboratory and center at the Institute.

But the considerations and the forces which grow out of our international dimensions are changing. Global politics, global economy, and especially the global environment are all signs of times to come. This is true not only for our graduates but for MIT as an institution. We have an international perspective in our approach to education, and in our research programs we are dealing increasingly with issues which are fundamentally international in character. The issue of global climate change, to which I have just referred, is a fine example of that. Whatever conclusions we come to about the significance of the greenhouse effect, and of the time scales and consequences of global warming, one thing is certain -- and that is that there are no solutions to these problems unless they are global in character. They must be addressed on a worldwide basis, and MIT will play an important role in this and other major issues that are international in character and significance.

As the vision of one world moves ever, and inexorably, closer to reality, there has been in some quarters over the past decade in the United States a growing and troubling parochialism. The antidote to the hurtful aspects of this movement, especially insofar as it impacts adversely on MIT and other research universities, must come from a renewed assessment of the many issues involved. Accordingly, the provost and I have commissioned a faculty group to undertake a "Study on the International Relationships of MIT" to help us better understand and come to grips with the role of MIT as a player on the world stage.

Pace, Coherence, Intellectual Impact of Education at MIT

Education -- particularly undergraduate education -- is at the center of MIT. I felt ten years ago, and I believe today, that we need to keep a special focus on our undergraduate educational programs. I say that in full recognition that MIT is an institution with multiple missions -- undergraduate education, graduate education, research, public service. All are important, but our central purpose is related to undergraduate education, and our undergraduate students are a continuous renewing force for the institution and for everyone associated with it. Eighteen-year-olds, when they come here, are open -- and extraordinarily so -- to new ideas, to new challenges, to new initiatives. They come with a kind of openness and wonderment and willingness to try new things which is almost indescribable. Each year, in late August, when the freshmen arrive on this campus, the electricity is palpable. These youngest students are not only a continuous renewing force, but they are, fundamentally, the intellectual glue that holds together this institution of five schools and twenty-two departments and countless interdepartmental laboratories and centers.

The significance of the Institute's commitment to undergraduate education and the significance of the undergraduates as the cohesive force for MIT was clearly recognized and applauded in the report of an evaluation team representing the New England Association of Schools and Colleges that reaffirmed the Institute's undergraduate degree accreditation, following a visit here last fall. Commenting on the academic program, that report said:

MIT provides an undergraduate education remarkable for its rigor, its demands, and its quality. Its undergraduate students are motivated, talented, industrious, and loyal to their institution, sharing a sense of satisfaction and pride in meeting and matching the demanding requirements of the faculty. They enjoy MIT and are its strongest advocates.

We are impressed, too, by the dedication of many members of the faculty, administration, and professional staff to whom we spoke, and their deep sense of concern for the quality of the undergraduate experience.

In the last few years, the MIT faculty has paid particular attention to the curriculum, to grading, and to the context -- in and out of the classroom -- in which education occurs. Those efforts that have focussed on review and revision of the undergraduate curriculum have been particularly intense. They are ongoing, and are far from finished. But significant steps have been taken. As examples, and only by way of illustration, I would cite the strengthening of our educational opportunities outside of science and engineering by the major revision in the General Institute Requirements in the humanities, arts, and social sciences; the further development of Athena, our system of high-powered workstations for educational enhancement; the integration of the Writing Requirement

into the curriculum; the decision by the faculty to establish a sequence in modern biology as part of the General Institute Requirement in science; and the appointment, for the first time, of an associate provost for the arts in response to the strong recommendation of a faculty committee.

All of these steps, and others, have been intended to help create the richer educational environment which many of us believe will be required for undergraduates who will come into their prime early in the new century. The structure of undergraduate engineering education in particular, at MIT and elsewhere, is quite generally considered to be overconstrained. In looking toward reform, the MIT Commission on Engineering Education has stressed that

Undergraduate education in engineering should prepare its graduates for leadership in technology, for professional excellence, and for rich lives of learning and reflection, through education in science and engineering with an emphasis on fundamentals, in essential partnership with the social sciences and the humanities, for the advancement of engineering and the betterment of society.

Yet in all of these developments we are neither moving toward nor seeking to become a general university. We intend to remain true to our founding mission, by which we were established “for the advancement and development of science and its application to industry, the arts, agriculture, and commerce.” But a new era will require a new breed of technologist, a new breed of alumnus, and in our undergraduate education we must do our best to anticipate those requirements and prepare our students not only for productive and rewarding careers in a new century, and in a new world, but also for a lifetime of independent and integrated learning and intellectual self-renewal.

As we think about the intellectual content of the undergraduate program, we need to have some cautions in mind. If there is one thing that I believe has not changed for the better in the past ten years, it is what has been called the pace and pressure of the place. There is still a kind of breathlessness in the undergraduate educational process, and, for that matter, in the graduate process as well. We all seem to have a tendency to try to do one more thing, take one more course, squeeze in one more activity, and place too little value on what can be learned from relaxing a bit, from learning a little more from one’s colleagues and peers, and from taking the pace a little slower. While I have talked for ten years about the notion that we would all be better off if we could turn the throttle back a bit, I have gotten very little resonance on that. That is an unresolved and significant issue related to the quality of the lives of most of us who study and work here. It needs to be continually thought about and, to the extent possible, addressed.

Quality of Life and Making a Pluralistic Community Work

As we enter this last decade of the twentieth century, we are all aware that higher education is about halfway through a continuous twenty-year decline in the number of young people coming of college age. When that age population begins to increase again at the beginning of the next century, the social and racial mix of the cohort will be enormously different from what it was in the 1960s and 1970s. It has been said, indeed, that the twenty-first century will be the first post-European century in American history. That is, an absolute majority of young people born in the United States will be born of parents of other than northern European background -- whether Asian, or African, or Hispanic. That will represent a major change in the character of our society and will be reflected as well in the mix of young people who attend college. Considering that, we need to recognize also that we have not been very effective, until the last few years, in reaching out to those portions of the population who are not of the historically dominant ethnic background in this country.

Mirroring in part our changing society, MIT undergraduates have changed in these past years from a majority of white males to a student body where no single group dominates. All today are minorities. Racial-ethnic minorities have become in the aggregate more than 40 percent of the freshman class, compared to 18 percent in 1980. At the start of the decade, fewer than one in five of our undergraduates were women, compared to one in three today. And white males are now 36 percent of the undergraduate student body as compared to 60 percent a decade ago. In the graduate school and on the faculty, however, white males still predominate overwhelmingly; and it is clear that major efforts are required on many fronts to increase the numbers of women and, especially, of minorities in these constituencies.

Nonetheless, we are becoming a more diverse community, and we need to pay particular attention, therefore, to fostering civility, mutual respect, and a shared sense of purpose. That was easier in earlier times, perhaps, when our mission was more tightly focused and the population was less diverse. Today there is a more pressing challenge for all -- faculty, students, staff -- to strive to learn from and live in harmony with people whose experience, outlook, talents, and expectations may be very different from their own and different from the historical character of MIT.

To understand and accept others as they are, we need the capacity to eschew stereotypes and prejudice and to examine critically our own systems of values. For our students especially, this is the essence of growth and development. We need the resolve to contribute to a climate of mutual respect and affirmation of each person's dignity and humanity as well as of our own. Put simply, mutual respect matters. And it will be absolutely essential to making our evolving pluralism work even better than it does.

Enhancing and Securing the Financial Foundation of MIT

I turn now to matters related to enhancing and securing our financial foundation. Securing that foundation is complicated by the fact that MIT's operating budget, left to itself, continuously grows out of balance. The reasons for that, which I have discussed on many occasions with the various constituencies of the Institute, are the limits on our income streams. This unstable state of our basic financial structure has been the rule for the nineteen years that I have been involved in the oversight of the operating budget. And we have not, any of us, over this long period of time discovered how to deal with the budget in a way that did not leave it subject to fragile balancing, and subject to growing out of balance. To fix this problem in a manner that has some permanence will require an invention that we haven't yet found. In the meantime, we must attack the problem with a planning and budgeting process of unrelenting vigor.

Almost everything we face -- problems and opportunities alike -- can be denumerated, of course, in dollars. The cost pressures, especially those most critical to our ability to support our faculty and students, are enormous. The pressures on faculty salaries and those associated with student aid create constant cost imperatives, as I have already noted. At a place like MIT we also have the permanent obligation to support new academic enterprises, for doing some things this year that we didn't do last, to keep in the forefront of what Vannevar Bush called "the endless frontier" of science and engineering.

We have, in addition, basic requirements for classroom and laboratory renewal and for occasional expansion of the physical plant, in a time when there is no longer any significant federal support for our necessary infrastructure. To help meet our most urgent facility needs we have employed a variety of approaches in recent years -- such as the novel organizational arrangement with the Whitehead Institute for Biomedical Research, renovating and recycling an old manufacturing building for graduate student housing, and giving special priority in our capital campaign to our indispensable need for a new biology building.

The lack of a national policy for a federal role in the building of academic research facilities has led to the growing practice of earmarking or otherwise allocating construction funds on bases often totally unrelated to the scientific merit of the project. Both directly and indirectly that is a cost to science. The federal government has also added in other ways to the cost squeeze on our universities, most notably in its constant drive to provide less, and sometimes considerably less, than full reimbursement for the expense of research.

That is perhaps inevitable in the present political climate, and it's undoubtedly going to continue. I find no policymaker in Washington who will agree anymore to the proposition that the government should pay the full cost of the research that it sponsors. One way or another, these legitimate expenses are going to be discounted and capped, to the

impairment of the health of our universities. Even more regrettably, there is today a querulous tone to academic relations with Washington that has changed the character of the association and diminished its effectiveness. This is a radical change from the years following World War II, when a government-university partnership began that brought to full flower the country's unsurpassed system of higher education and its world leadership in science and technology. We need to rebuild both the sense and the substance of that old partnership.

The Congress is struggling, as we are all aware of course, with the important and seemingly intractable budget deficit. And it seems unable, or at least finds it very hard, to support the proposition that investment in higher education, including research and student financial aid, is truly an investment in the long-term national interest that ought to be regarded differently from all those other things it is concerned about in trying to balance the budget.

Happily, MIT alumni and friends in the private sector subscribe to the concept of investment and, as a result, the progress of the *Campaign of the future* has been truly astonishing. Indeed, driven by the enthusiasm and generosity of MIT's donors and volunteers, the *Campaign* has achieved such a rapid rate of success that in March of 1990 the Corporation voted to raise its goal from \$550 million to \$700 million, a 27 percent increase. And by the end of the 1990 fiscal year, the campaign total had reached \$517 million, with a number of important new records established. These included the \$103 million in cash and securities and the more than \$16 million raised by the Alumni Fund -- both new highs for one year.

While the campaign goals have been increased, in light of this heartening record, the priorities themselves are little changed from those set down at the start of the drive in October of 1987. Increasing MIT's overall endowment remains a most critical aim. The priorities, as revised, fall into five areas: Faculty chairs, \$110 million; Student Support, \$120 million; Academic Programs, \$300 million for a wide range of areas such as brain science, materials, engineering education, and management of technology, to name a few; Facilities, \$70 million, with special priority for the urgently needed biology building; and, finally, \$100 million in Unrestricted Funds to provide the flexibility to respond to unexpected needs or important new fields.

With two years remaining in the *Campaign*, I am confident that an effective volunteer corps, a dedicated staff, and the continuing generosity of individuals, corporations and foundations will help MIT reach, and even exceed, the most ambitious goal we have ever set.

Conclusion

In trying to address at MIT the many educational issues and intellectual opportunities of the last decade, I have tried to maintain that delicate balance between preservation and transformation. Change doesn't come easily to institutions or individuals. And it has been for me a puzzlement as to why it is that our faculty and students -- separately and together -- generally have quite open and liberal views on almost any question, except when it comes to institutional change. Then they can be colossally conservative. I don't fully understand it, but I think it relates in a measure to a sense of parochialism which we occasionally find at MIT. We seem sometimes to have the attitude that the way we do things is, if not the only way, surely the best way. We could learn some things from other places -- as has been impressed upon me as I watched the progress of my own four children through four very different colleges and different undergraduate experiences.

I have seen my role over this past decade as helping the institution try to preserve its historic intellectual focus and its insistence on excellence, while at the same time encouraging the faculty and the staff to transform our programs to serve the evolving needs of the future. In all of this, a major goal has been to sustain and improve an environment that allows the faculty and the students to do their best.

The hard part in this, of course, is making the distinctions between what to preserve and what to transform. And the second, even harder, part is trying, once you've figured out what ought to change, to make it happen.

There have been, in these ten years, enormous rewards. It is rewarding to learn something new and significant practically every day, and there are countless opportunities for that around here. It has been very rewarding to get to know so many people -- faculty, students, staff, alumni -- for whom MIT holds a special place. And it has been, above all, most rewarding to be able to serve this university in the best way I can and to give back in small measure some of what I have received in the nearly four decades that I have been privileged to be part of this great institution.

In all of this I have had a primary, unflagging partner, someone who has been an ambassador of the Institute throughout the world, a community builder here at home, and a model of what caring, committed service is all about. I refer, of course, to Priscilla Gray. Because the Institute has been part of our life together for more than thirty years, we have had the good fortune to work together for MIT for that span of time. We now look forward in our new roles to continuing that most pleasant of occupations.

PAUL E. GRAY
September 1990

In Special Recognition

This year's report is an occasion for me to salute many of my close colleagues who have or soon will be making career changes.

First, of course, is David S. Saxon, Chairman of the Corporation, who is retiring after seven years in that post. An MIT alumnus, Dr. Saxon's distinguished academic career at the University of California enabled him to bring a fresh perspective and new ideas to the Institute's trusteeship, and under his leadership the organization and activities of the Corporation took on a renewed vigor. I could not have wished for a more supportive colleague as chairman and confidential adviser, and no board could have received more committed, loyal, and creative leadership from its chairman.

Late in January, my closest colleague in the day-to-day administration of the Institute, John M. Deutch, announced that he would be stepping down after five years as provost. Professor Deutch, the Karl Taylor Compton Professor of Chemistry, intends to return to teaching and research in physical chemistry and to continue his work on public policy issues. He is clearly the most effective academic administrator I have ever encountered, combining an extraordinary grasp of the intellectual scope of the Institute with great skill and effectiveness as an academic leader and budget manager. His service as provost has strengthened the Institute, and I feel very fortunate to have had him as a colleague and friend.

In February, Ann F. Friedlaender, dean of the School of Humanities and Social Science, announced her intention to resign as dean. Professor Friedlaender, who was the first woman to become an academic dean at MIT (in September 1984), has been deeply involved in the ongoing reassessment of the Institute's undergraduate program. She has been a thoughtful, persuasive leader in building programmatic bridges with the other Schools (Engineering, in particular), as well as in bringing about curriculum changes that have strengthened the humanities, arts and social sciences in the core academic program. During her tenure, MIT also established its first formal program for minor studies in these fields. Dr. Friedlaender, who holds dual appointments as professor in the Departments of Economics and Civil Engineering, will be returning to the Economics Department to teach, do research, and pursue her interests in economics and public policy.

In June, Professor Philip S. Khoury was named acting dean of the School of Humanities and Social Science. A professor of history, Dr. Khoury has been associate dean of the School of Humanities and Social Science since 1987 and has been much involved in the School's ongoing reassessment of the undergraduate curriculum.

In the spring, Shirley M. McBay, dean for student affairs since April 1980, resigned her post effective June 30, 1990 and began a two-year leave from MIT to become founding

president of the national Quality Education for Minorities Network -- an enterprise that will focus on improving pre-college education. This program grows out of a two-year national study conceived and directed by Dean McBay. Dr. McBay brought wisdom and high standards to every aspect of her work at MIT. With clarity, dedication, and perseverance, she helped move us towards the goal of being a community characterized by diversity and civility.

Professor Arthur C. Smith, professor of electrical engineering, graduate officer in the Department of Electrical Engineering and Computer Science, and former chairman of the faculty, was appointed to a one-year term as acting dean for student affairs, effective July 1.

In June, Kenneth A. Smith, Associate Provost, Vice President for Research, and Director of Whitaker College, announced his intention to relinquish those responsibilities, after a decade of distinguished administrative service. Professor Smith, who holds the Gilliland Chair in Chemical Engineering, has provided thoughtful guidance and policy direction for several of the large interdepartmental laboratories at MIT, has helped work through major changes in academic organization, and has moved us toward much more effective policies and practices in the area of intellectual property.

In the spring, Gerald L. Wilson, dean of the School of Engineering since 1981, announced his intention to resign. Dean Wilson, the Vannevar Bush Professor, holds a joint appointment in the Department of Electrical Engineering and Computer Science and the Department of Mechanical Engineering. During his tenure as dean, the School of Engineering has played a key role in helping create and develop several significant Institute programs, notably Project Athena, the School of Engineering Commission on Undergraduate Education, and the Leaders for Manufacturing Program. Dean Wilson's focus in the School on issues of national productivity was a major factor leading to the appointment and ultimate success of the MIT Commission on Industrial Productivity, and he has been a leading spokesman on the need to make fundamental changes in the education of engineers nationwide.

In July of last year, Walter L. Milne, Assistant to the Chairman and to the President, announced his plans to retire. Mr. Milne, who began his career at MIT in 1951 as a member of the News Office, joined the Office of the President in 1958 during the tenure of Julius A. Stratton. He has served MIT's chairmen and presidents ever since, and we have all benefitted greatly from his wisdom and sound judgment. Walter Milne is "Mr. MIT" in the Cambridge community and on Capitol Hill, fostering mutual understanding, respect, and clear communication among politicians, presidents, and professors.

In the spring, Professor David Baltimore, the founding director of the MIT-affiliated Whitehead Institute for Biomedical Research, was selected President of Rockefeller

University in New York. On July 1, Gerald R. Fink, American Cancer Society Professor of Genetics at the Whitehead Institute and in the Department of Biology, assumed the post of Director of the Whitehead Institute.

New department or program heads announced during the past year were: Lawrence S. Bacow, Director, Center for Real Estate Development; Alan Brody, Director, Music and Theater Arts Section, Department of Humanities; Claude R. Canizares, Director, Center for Space Research; Ronald C. Davidson, Associate Director, Plasma Fusion Center; Isabelle de Courtivron, Head, Foreign Languages and Literature Section, Department of Humanities; Simon Foner, Associate Director, Francis Bitter National Magnet Laboratory; Robert G. Griffin, Associate Director, Francis Bitter National Magnet Laboratory; Earll M. Murman, Head, Department of Aeronautics and Astronautics; John W. Negele, Director, Center for Theoretical Physics; Wayne O'Neil, Head, Department of Linguistics and Philosophy; Peter C. Perdue, Head, History Section, Department of Humanities; Donald A. Schon, Head, Department of Urban Studies and Planning; and Peter Temin, Head, Department of Economics.

Major changes in the Institute's central administration during the year included the appointment or promotion of the following individuals: Harmon E. (Gene) Brammer, Director, Physical Plant; Thomas R. Moebus, Director, Industrial Liaison Program; Judy Jackson (J.J.) Pitts, Assistant Dean for Student Affairs and Director of the Office of Minority Education; and Peter Reich, Chief of Psychiatry, Medical Department.

* * *

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

Three MIT faculty members were elected to the National Academy of Engineering. Elected were: Michael L. Dertouzos, Robert H. Kingston, and Ronald L. Rivest. All three are faculty members in the Department of Electrical Engineering and Computer Science.

New members of the National Academy of Sciences this year included three MIT faculty members and an MIT senior research associate. Those elected were: Kenneth L. Hale, Ferrari P. Ward Professor of Modern Languages and Linguistics in the Department of Linguistics and Philosophy; Peter Molnar, senior research scientist in the Department of Earth, Atmospheric, and Planetary Sciences; Paul R. Schimmel, professor of biochemistry and biophysics in the Department of Biology; and Vernon R. Young, professor of nutritional biochemistry in the School of Science's Clinical Research Center.

Elected in the late spring as new Fellows of the American Academy of Arts and Sciences were: Olivier Blanchard, professor of economics in the Department of Economics and J. David Litster, Director of the Francis Bitter National Magnet Laboratory and professor in the Department of Physics.

In July 1989, John Harbison, the nationally recognized composer who has been a member of the MIT music faculty for twenty years, was the recipient of a John D. and Catherine T. MacArthur Foundation fellowship. The fellowships were created to allow extraordinarily talented individuals from all walks of life to work at their highest potential without interference and free of financial constraints. In its announcement, the MacArthur Foundation said: "John Harbison...is a composer, performer, conductor, writer, organizer and promoter of contemporary music. His knowledge of Western music is extensive, and he is an important and articulate essayist."

Professor Marvin L. Minsky, whose contributions have made him one of the most influential leaders in the field of artificial intelligence, was awarded the prestigious Japan Prize for 1990 in the field of technology of integration. Awarded since 1985, the Japan Prizes are given to scientists who are recognized as having accomplished original and outstanding achievements in science and technology, thus contributing to the progress of science and technology and the promotion of peace and prosperity of humankind. Dr. Minsky was cited for the "establishment of artificial intelligence as a new discipline and the proposal of its fundamental principles." Dr. Minsky, the Toshiba Professor of Media Arts and Sciences in the Department of Electrical Engineering and Computer Science and the Killian lecturer for the 1989-90 year, is noted in the field of artificial intelligence for his approaches to problems of symbolic representation, knowledge representation, semantics, machine perception, and learning.

Professor T. Francis Ogilvie, head of the Department of Ocean Engineering, was named the first recipient of the William H. Webb Medal "for outstanding contributions to education in naval architecture, marine or ocean engineering." The gold medal was awarded by the Society of Naval Architects and Marine Engineers.

In the fall, Professor Eugene B. Skolnikoff, of the Department of Political Science and the Center for International Studies, received the Order of the Rising Sun, Gold Rays, Neck Ribbon from the Government of Japan for "his many contributions to the promotion of friendship and mutual understanding between Japan and the United States." The award recognized in particular Professor Skolnikoff's work on energy-related issues.

Dr. Jay W. Forrester, Germeshausen Professor of Management, Emeritus, in the Sloan School of Management, was named corecipient of the National Medal of Technology along with Robert E. Everett, who received the S.M. in electrical engineering from MIT and is the former president of the Mitre Corporation. The medal, which was awarded by

President George Bush, recognizes individuals and companies that have made exceptional contributions to the well-being of the nation through the development or application of technology. The Medal of Technology citation praised Professor Forrester and Mr. Everett "for their creative work in developing technologies and applying computers to real-time applications. Their important contributions proved vital to national and free world defense and opened a new era of world business." Both Dr. Forrester and Mr. Everett did their groundbreaking computer work after World War II in MIT's Digital Computer Laboratory, where Professor Forrester was director and Mr. Everett associate director.

Within the Institute, Professor George H. Buchi, one of the world's leading figures in organic chemistry, was selected as the 1990-91 recipient of the James R. Killian Jr. Faculty Achievement Award. The Killian Award recognizes extraordinary professional accomplishments and service to MIT. It was established in 1971 as a tribute to the late Dr. Killian, MIT's tenth president and former chairman of the Corporation. The selection committee's citation credited Dr. Buchi, the Camille and Henry Dreyfus Professor of Chemistry, for his contributions in photochemistry, natural products, and molecular toxicology, which comprise cornerstones of these diverse areas of organic chemistry. The citation went on to say: "His creativity and style in organic chemistry have inspired fundamental work by others....His contributions in research and education have added to the quality of life globally, and his colleagues and students have derived direct benefit from his wisdom, dedication to excellence, and friendship."

In the spring, Stephen L. Buchwald, Associate Professor of Chemistry, was named the 1990 recipient of the Harold E. Edgerton Faculty Achievement Award. The award is given annually to a junior faculty member in recognition of exceptional teaching, research, and scholarship. An innovative and creative organometallic chemist, Professor Buchwald was cited by the selection committee for his research "at the heart of chemistry: making new molecular substances, proving their structure, and establishing their properties" and for his interest in and dedication to the education of his students.

* * *

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

Richard B. Adler died on February 6 at the age of 67. A leading figure in semiconductor electronics, electromagnetic theory, and circuit theory, Professor Adler was instrumental in bringing transistor-based, solid-state electronics into the undergraduate engineering curriculum. He began teaching at MIT in 1949, led the solid-state and transistor group at the Lincoln Laboratory from 1951 to 1952, was associate head of the Department of

Electrical Engineering and Computer Science from 1978 to 1989, and codirected the Microsystems Technology Laboratories from 1989 until his death.

MIT Corporation member E. Rudge Allen died on January 5. He was 62 years old. Mr. Allen received bachelor's degrees from MIT in 1948 and 1949 in chemical engineering and general engineering, respectively. He served on the Alumni Fund Board from 1972 to 1975, was vice president of the Alumni Association from 1983 to 1986, and served on the Corporation Development Committee since 1973. Mr. Allen was Executive Vice President and Director of Fayez Sarofim & Co. of Houston.

Horacio Caminos, professor emeritus of architecture, died on February 18 at the age of 75. Professor Caminos's work focused primarily on the design of lowcost housing for developing countries, and in the School of Architecture and Planning he created a program in urban settlement design for students from developing countries. From 1940 to 1950 Professor Caminos taught in Argentina at the University of Tucuman and in 1952 became professor of architecture at North Carolina State College. Teacher, architect, and recipient of numerous awards, he authored *Urbanization Primer* (1978) and *Education or Catastrophe*. Professor Caminos retired from MIT in 1984 after twenty-three years on the faculty.

Harold E. "Doc" Edgerton, 86, died on January 4. Best known as the inventor of the stroboscope, used in high-speed photography, and as the MIT professor whose office door was always open, Dr. Edgerton was also a deep-sea explorer, marine archæologist, and entrepreneur. After graduating from the University of Nebraska with a degree in electrical engineering in 1925, he joined General Electric Co. in Schenectady, New York for a year. In 1927 he received a master's degree and in 1931 the Sc.D., both from MIT. He joined the MIT faculty in 1932. In 1952 at the request of the National Geographic Society, he collaborated with Jacques Cousteau to develop an underwater camera. He was a major contributor to the development of scanning sonar as a tool for underwater exploration. Dr. Edgerton was the recipient of numerous awards and honors, the author of nearly 150 articles, and was a cofounder of EG&G, Inc., a company specializing in electronic technology.

Yuk Wing Lee, professor emeritus of the Department of Electrical Engineering and Computer Science, died on November 8 at the age of 85. Professor Lee received the S.B. degree in 1927, the S.M. in 1928, and the Sc.D. in 1930, all from MIT. After holding professorships at three universities in China, he joined the MIT faculty in 1946, became professor in 1960, and retired in 1969. Known for his pioneering work in statistical communication theory, Professor Lee authored many articles, papers, and the book, *Statistical Theory of Communication*.

J. C. R. Licklider, professor emeritus in the Department of Electrical Engineering and Computer Science, died in June at the age of 75. Recognized for his pioneering work on computer timesharing, virtual memory, and resource sharing, as well as on computer-human interaction, Professor Licklider joined the MIT faculty as an associate professor in 1950. In 1957, he went to Bolt Beranek and Newman, Inc. as vice president, and in 1962 he became director for information processing techniques and for behavioral sciences with the Advanced Research Projects Agency. In 1968 he returned to MIT as director of Project MAC and professor in the Department of Electrical Engineering. With the exception of 1974-75, when he directed the Information Processing Techniques Office in Washington, he remained at MIT until his death.

Philip Mandel, professor emeritus in the Department of Ocean Engineering, died on December 18. He was 69. A 1942 graduate of the University of Michigan with degrees in naval architecture and mathematics, his research interests were in ship design, ship maneuvering, control and seakeeping. Prior to coming to MIT in 1957, he was a naval architect with the Bureau of Ships. The author of two texts, *Ship Maneuvering and Control* and *Water, Air, and Interface Vehicles*, Professor Mandel retired from MIT in 1980 after twenty-three years on the faculty.

H. W. McCurdy, MIT Corporation member since 1945, died on November 13. Mr. McCurdy held an MIT degree in mechanical engineering (1922). He was captain of the first varsity crew at MIT and recently provided a gift to the crew program, establishing the H. W. McCurdy Coaching Chair. At the time of his retirement in 1963, he was chairman of the board of the Puget Sound Bridge and Dredging Company.

Professor Emeritus John T. Norton died on July 18 at the age of 90. While at MIT, he received the S.B. degree in physics in 1918, joined the faculty in 1926, and received the Sc.D. degree in 1932. As author, teacher, and researcher, his interest lay in the interaction of physics and metallurgy. As an MIT administrator, he served from 1956 to 1958 as chairman of the faculty and during 1961 as acting dean of the Graduate School. He retired from MIT after thirty-eight years of faculty service. Dr. Norton was one of the founders of AMRAY, Inc., the nation's largest manufacturer of scanning electron microscopes.

Egon Orowan, 87, of the Department of Mechanical Engineering, died on August 3. In 1950 Professor Orowan accepted a visiting faculty position at MIT and joined the faculty later that same year. His primary research interest was the concept of dislocations, but also included the mechanisms of earthquakes and formation of mountains. His undergraduate training in engineering paved the way for later recognition as a unique teacher of materials science. Professor Orowan retired from MIT in 1968.

Professor H. P. Whitaker, professor emeritus of the Department of Aeronautics and Astronautics, died on November 22. Professor Whitaker received the S.B. degree from MIT in 1944 and the S.M. in 1959. He pioneered research on automatic flight control systems for airplanes and rockets and served as consultant to the Draper Laboratory. Professor Whitaker joined the MIT faculty in 1947 and retired in 1983.

Walter Wrigley, professor emeritus of instrumentation and astronautics, died on November 9; he was 76. Professor Wrigley received the S.B. in physics from MIT in 1934 and the Sc.D. in 1941. He worked for the Sperry Gyroscope Company from 1940 to 1946 and returned to MIT in 1946 as assistant director of the Instrumentation Laboratory, which later became the Charles Stark Draper Laboratory. He became associate professor in 1946 and educational director of the Instrumentation Laboratory in 1956. Professor Wrigley wrote several papers and books on navigational instruments and counts among his graduate students four who later became astronauts. He retired from MIT in 1975.

Statistics for the Year

Registration

In 1989-90 student enrollment was 9,536, compared with 9,500 in 1988-89. This total was comprised of 4,307 undergraduates (compared with 4,325 the previous year), and 5,229 graduate students (compared with 5,175 the previous year). The international student population was 2,044, representing 8 percent of the undergraduate and 32 percent of the graduate populations. These students were citizens of 102 countries. Students with permanent residence status are included with U. S. citizens.

In 1989-90, there were 2,519 women students (1,460 undergraduate and 1,059 graduate) at the Institute, compared with 2,429 (1,412 undergraduate and 1,017 graduate) in 1988-89. In September 1989, 349 first-year women entered MIT, representing 33 percent of the freshman class.

In 1989-90, there were, as self-reported by students, 1,798 minority students (1,449 undergraduate and 349 graduate) at the Institute compared with 1,637 (1,331 undergraduate and 306 graduate) in 1988-89. Minority students included 350 Black Americans (non-Hispanic), 25 Native Americans, 394 Hispanic Americans and 1,029 Asian Americans. The first-year class entering in September 1989 included 421 minority students, representing 40 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1989-90 included 1,101 bachelor's degrees, 1,087 master's degrees, 36 engineer's degrees, and 509 doctoral degrees -- a total of 2,733 (compared with 2,794 in 1988-89).

Student Financial Aid

During the academic year 1989-90 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 an increase in the amount of Technology Loans and in Guaranteed Student Loans obtained from commercial sources; but awards from the Perkins Loan Program decreased.

A total of 2,475 undergraduates who demonstrated the need for assistance (57 percent of the enrollment) received nearly \$24 million in grant aid and almost \$9 million in student loans from all sources. The total, almost \$33 million, represents a 15 percent increase in aid compared to last year.

Grant assistance to undergraduates was provided by \$8.3 million in income from the scholarship endowment, by \$1.1 million in outside gifts, by \$3 million in federal grants (including ROTC scholarships), and by \$2.1 million in direct grants from non-federal outside sources to needy students. In addition, \$9.6 million 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 \$141,000, and the MIT Opportunity Awards which accounted for just under \$500,000. An additional 436 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was increased by the addition of \$8.3 million in new funds (exceeding by far the largest previous annual increase), raising the principal of the endowment by 15.4 percent, to \$62.3 million.

Loans totaling nearly \$9 million were made to needy undergraduates -- an 11 percent increase from last year. Of this amount \$1.2 million came from the Technology Loan Fund, \$3.2 million from the Perkins Loan Program, and \$4.6 million obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained \$2.6 million from the Technology Loan Fund. In addition, \$343,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, \$2.9 million, represents a 5 percent increase from last year's level. Graduate students obtained \$3.5 million from outside sources under the Guaranteed Student Loan Program -- 7 percent less than last year. The total loaned by MIT to both graduate and undergraduate students was \$11.8 million, a 9 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 the records based on the fiscal year that are reported by the Comptroller or the Treasurer)

Career Services and Preprofessional Advising

The increasing emphasis in industry on product quality has led many companies to put a heavier stress on quality in their hiring, which has kept a flow of employers coming to MIT in spite of generally reduced hiring needs. Indeed, the flow has even increased. A total of 477 employers made recruiting visits in 1989-90, more than in any year since the 1960s.. They included 457 private companies and non-profit organizations, and twenty government agencies. One out of six came from the West Coast.

Perhaps discouraged by the news of fewer opportunities, fewer students had interviews -- 1,538 compared with 1,830 the year before -- but they had over 10,000 interviews, more than in 1988-89.

The throng of recruiters did not translate into much of a boost in salaries. For the second year in a row, offers in many technical areas barely kept pace with inflation. In Electrical Engineering and Computer Science, the department with the most students reporting offers, offers to bachelors in computer science were up 4.6 percent (to \$36,100) -- roughly keeping up with the Consumer Price Index -- but offers to bachelors in electrical engineering were up only 2.3 percent (to \$34,300) and offers to masters rose 2.4 percent (to \$41,700). Offers to Ph.D.s and Sc.D.s, averaging \$55,000, did not rise at all. Better news came from Chemical Engineering, where offers to bachelors rose 6.4 percent (to \$35,700) and offers to masters rose 4.9 percent (to \$38,400). The Career Development Office at the Sloan School reports offers by manufacturing firms to Sloan master's candidates rising at a similar rate -- 4.4 percent -- but offers from non-manufacturing firms rising as much as 7.1 percent.

The number of MIT applicants to medical school dropped back slightly to 119, compared with 130 in 1988-89. The total is in line with previous years, but with a trend towards students deferring their candidacy rather than applying as seniors. This year's applicant pool consisted of seventy-six undergraduates, six graduate students, and thirty-seven alumni. Final results are not yet in but we know that all of the graduate students were accepted, 79 percent of the undergraduates, and 70 percent of the alumni. The overall acceptance rate to date is 77 percent.

Gifts

Gifts, grants and bequests to MIT from private donors in 1989-90 were \$113.2 million, the Institute's highest historical gift total. This amount includes cash, securities, and real estate gifts totaling \$103.2 million, and \$10 million of equipment gifts. The Alumni Fund reported gifts of \$16.2 million, a new high and 12 percent above last year. The Fund benefitted from the increase in the size of gifts from thousands of donors -- a result of 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 517.5 million by the end of the fiscal year. This is an increase of almost exactly \$100 million since the previous year end. In March, the Corporation voted to increase the *Campaign* goal from \$550 million to \$700 million by the end of June 1992. 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 \$1.06 billion -- an increase of 12.3 percent over 1988-89. Education and general expenses -- excluding the direct expenses of departmental and interdepartmental research and the Lincoln Laboratory -- amounted to \$446.9 million during 1989-90, compared with \$405.3 million in 1988-89. The direct expenses of departmental and interdepartmental sponsored research on campus increased from \$198.8 million to \$220.7 million, and direct expenses of the Lincoln Laboratory's sponsored research increased from \$343.1 million to \$396 million. Current revenues used to meet the Institute's operating expenses totaled \$1.05 billion, augmented by \$7.5 million in current gifts and \$3.5 million of other fund balances.

At the end of the 1990 fiscal year, the Institute's investments, excluding retirement funds, student notes receivable, and amounts due from educational plant, had a book value of \$1.29 billion and a market value of \$1.72 billion compared to last year's book value of \$1.14 billion and market value of \$1.52 billion.

Physical Plant and Campus Environment

Major design and construction activities this year included the substantial completion of a project to renovate an existing early 20th century masonry manufacturing complex to a 190-bed graduate student residence. This air-conditioned facility at 143 Albany Street contains eighty-eight apartments (studio to four bedrooms) and was scheduled for occupancy this past summer. Construction of the South Hall Ring at the Bates Linear Accelerator continued during the year, and work continues on the renovation and expansion of the Rotch Library in Building 7. The new addition will expand the library from 9,800 to 27,000 gross square feet. Planning and design work for the new Biology Building at 31 Ames Street continues. Construction of the proposed six-story facility is scheduled to begin early in 1991, with completion expected in mid to late 1993. In March, work began on renovations to the President's House, which include handicap access, air conditioning in the public spaces, and an improved heating and ventilating system. The planning and design work for the conversion of the building at 38 Memorial Drive to academic uses is also underway. Demolition of the Office of Naval Research Generator Building, which houses the 10-MV Van de Graaf generator, was begun.

The benefits of Phase I of the Institute's energy conservation rebate program, which was completed this year, were evident. At current prices, the Institute will realize an annual net savings of over \$1 million as a result of this program. The success of Phase I has generated a new, more permanent program, Phase II, which is just beginning.

As a conservation measure, MIT has initiated a paper recycling program to recover all white ledger and computer paper discarded at the Institute. A pilot program was

implemented in several East Campus buildings this spring. The response was so positive that the program is now being expanded throughout MIT.

After many failed attempts, the Institute was finally successful in purchasing a piece of property for the purpose of housing Alpha Phi Sorority. The purchase of the property, located at 477-479 Commonwealth Avenue in Boston, was made conditional on Alpha Phi's securing zoning and licensing approval for the use of the buildings as a sorority house. After a long and complex process, the necessary permits were obtained. The planning and design process for the renovation of the property was initiated, with the expectation that members of Alpha Phi will occupy the house in the summer of 1991.

Personnel Changes

CORPORATION

DEATHS

E. Rudge Allen
Member

H. W. McCurdy
Life Member, Emeritus

CHANGES OF APPOINTMENT

Jerome B. Wiesner
Life Member, Emeritus

ELECTIONS

Denis A. Bovin
Member

Colby H. Chandler
Life Member

Jerome H. Grossman
Member

John M. Hennessy
Member

James A. Levitan
Member

Edward H. Linde
Member

Bernard Loyd
Member

David S. Saxon
Life Member

Emily V. Wade
Life Member

Harris Weinstein
Member

MEMBERS EX-OFFICIO

Paul E. Gray
Chairman
Massachusetts Institute of
Technology

Christian J. Matthew
President
Alumni Association

Charles M. Vest
President
Massachusetts Institute of
Technology

TERMS EXPIRED

Joan T. Bok
Member

Michael M. Koerner
Member

Fuad U. Muhammad
Member

Robert J. Richardson
Member

Robert A. Swanson
Member

FACULTY

DEATHS

Richard B. Adler
Department of Electrical
Engineering and Computer
Science

Harold E. Edgerton
Institute Professor

Joseph C. R. Licklider
Department of Electrical
Engineering and Computer
Science

H. Phillip Whitaker
Department of Aeronautics
and Astronautics

RETIREMENTS

Benjamin L. Averbach
Professor
Department of Materials
Science and Engineering

Michael Driscoll
Professor
Department of Nuclear
Engineering

Bernard T. Feld
Professor
Department of Physics

Harry C. Gatos
Professor
Department of Materials
Science and Engineering

William E. Griffith
Professor
Department of Political
Science

Norman Ham
Professor
Department of Aeronautics
and Astronautics

Carl Kaysen
Professor
Program in Science,
Technology, and Society

James L. Kinsey
Professor
Department of Chemistry

Claire J. Kramsch
Professor
Foreign Languages and
Literatures Section

Boris Magasanik
Professor
Department of Biology

James W. Mar
Professor
Department of Aeronautics
and Astronautics

Leo Marx
Professor
Program in Science,
Technology, and Society

Robert E. Mc Master
Professor
History Section

William F. Schreiber
Professor
Department of Electrical
Engineering and Computer
Science

M. Gene Simmons
Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Benson Snyder
Professor
Office of the Provost

RESIGNATIONS

Professor

David Botstein
Department of Biology

Gregory A. Petsko
Department of Chemistry

Harold M. Stark
Department of Mathematics

Gregory J. Yurek
Department of Materials
Science and Engineering

Associate Professor

Ranko Bon
Department of Architecture

Michael A. Celia
Department of Civil
Engineering

John C. Henderson
Sloan School of
Management

Dale Karr
Department of Ocean
Engineering

Bruce R. Musicus
Department of Electrical
Engineering and Computer
Science

Ramesh S. Patil
Department of Electrical
Engineering and Computer
Science

David A. Rudman
Department of Materials
Science and Engineering

Garth Saloner
Sloan School of
Management

David B. Shmoys
Department of Mathematics

Donca Steriade
Department of Linguistics
and Philosophy

Eva Tardos
Department of Mathematics

Nicholas Warner
Department of Mathematics

Assistant Professor

Philippe Aghion
Department of Economics

Thomas Paul Griffin
Department of Chemical
Engineering

B. Gabriel Kotliar
Department of Physics

Lode Li
Sloan School of
Management

Deborah L. Marlino
Sloan School of
Management

Gregory J. Mehos
Department of Chemical
Engineering

John Parsons
Sloan School of
Management

Jason Phipps-Morgan
Department of Earth,
Atmospheric, and Planetary
Sciences

Glen D. Rennels
Department of Electrical
Engineering and Computer
Sciences

PROMOTIONS

To Professor

Jeanne S. Bamberger
Music and Theater Arts
Section

John S. Carroll
Sloan School of
Management

Rick L. Danheiser
Department of Chemistry

Randall Davis
Sloan School of
Management

David C. Gossard
Department of Mechanical
Engineering

David M. Halperin
Literature Section

Neville Hogan
Department of Mechanical
Engineering

Chi-Fu Huang
Sloan School of
Management

Ian H. Hutchinson
Department of Nuclear
Engineering

Frank T. Leighton
Department of Mathematics

Jae S. Lim
Department of Electrical
Engineering and Computer
Science

Thomas W. Malone
Sloan School of
Management

Roger G. Mark
Department of Electrical
Engineering and
Computer Sciences

Marcia K. Mc Nutt
Department of Earth,
Atmospheric, and Planetary
Sciences

Steven Pinker
Department of Brain and
Cognitive Sciences

Julio J. Rotemberg
Sloan School of
Management

Herbert H. Sawin
Department of Chemical
Engineering

Warren P. Seering
Department of Mechanical
Engineering

Michael F. Sipser
Department of Mathematics

Thomas M. Stoker
Sloan School of
Management

Stephen J. Tapscott
Literature Section

To Associate Professor

Baruch Awerbuch
Department of Mathematics

Stephen L. Buchwald
Department of Chemistry

Michael A. Celia
Department of Civil
Engineering

Marie B. Chow
Department of Biology

William J. Dally
Department of Electrical
Engineering and Computer
Science

Randall M. Dole
Department of Earth,
Atmospheric, and Planetary
Sciences

Charles H. Fine
Sloan School of
Management

William Q. Hubbard, Jr.
Department of Architecture

Merrie G. Klapp
Department of Urban
Studies and Planning

Mark A. Kramer
Department of Chemical
Engineering

Robert J. Ledoux
Department of Physics

Lisa M. Lynch
Sloan School of
Management

Tod Machover
Media Arts and Sciences
Section

Paul T. Matsudaira
Department of Biology

Barbara J. Meyer
Department of Biology

Shahryar Motakef
Department of Mechanical
Engineering

Jean-Pierre Revol
Department of Physics

Nancy L. Rose
Sloan School of
Management

David B. Shmoys
Department of Mathematics

Jean-Jacques E. Slotine
Department of Mechanical
Engineering

Charles Stewart III
Department of Political
Science

Kamal Youcef-Toumi
Department of Mechanical
Engineering

David Zeltzer
Media Arts and Sciences
Section

**CHANGES OF
APPOINTMENT**

Edith K. E. Ackerman
Fukutake Career
Development Assistant
Professor of Research in
Education
Media Arts and Sciences
Section

Boris Altshuler
Associate Professor of
Physics
Department of Physics

Jeanne S. Bamberger
Section Head and Professor
Music and Theater Arts
Section

David J. Benney
Department Head and
Professor
Department of Mathematics

Gabriel R. Bitran
The Nippon Telegraph and
Telephone Professor of
Management
Sloan School of
Management

Peggy Cebe
Esther and Harold E.
Edgerton Assistant Professor
Department of Materials
Science and Engineering

Yet-Ming Chiang
Kyocera Associate Professor
of Ceramics
Department of Materials
Science and Engineering

Michael A. Cusumano
Mitsubishi Career
Development Assistant
Professor of Management
Sloan School of
Management

Srinivas Devadas
Analog Devices Career
Development Assistant
Professor of Electrical
Engineering
Department of Electrical
Engineering and Computer
Science

Peter S. Donaldson
Section Head and Professor
of Literature
Literature Section

John J. Donovan
Adjunct Professor of
Management
Sloan School of
Management

Ira Dyer
Weber-Shaughness
Professor
Department of Ocean
Engineering

Markus Flik
Lynde and Harry Bradley
Assistant Professor
Department of Mechanical
Engineering

Lee Gehrke
Lawrence J. Henderson
Associate Professor of Health
Sciences and Technology
Harvard-MIT Division of
Health Sciences and
Technology

Robert S. Gibbons
Pentti J. K. Kouri Career
Development Assistant
Professor of Economics
Department of Economics

David K. Gifford
Karl R. Van Tassel Career
Development Associate
Professor of Computer
Science and Engineering
Department of Electrical
Engineering and Computer
Science

Robert G. Griffin
Professor
Department of Chemistry

Bradford H. Hager
Cecil and Ida Green
Professor of Earth Sciences
Department of Earth,
Atmospheric, and Planetary
Sciences

Nicole Herbots
Carl Richard Soderberg
Assistant Professor of
Electronic Materials
Department of Materials
Science and Engineering

Thomas A. Herring
Kerr-McGee Junior
Development Associate
Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Dorothy Hosler
Assistant Professor of
Archaeology and Ancient
Technology
Anthropology / Archaeology
Program

Richard Hynes
Department Head and
Professor
Department of Biology

Vernon M. Ingram
Director of Experimental
Study Group, John and
Dorothy Wilson Professor,
and Professor of Biology
Department of Biology

Jean E. Jackson
Section Head and Professor
Anthropology / Archaeology
Program

Mark J. Jakiela
Flowers Career Development
Assistant Professor
Department of Mechanical
Engineering

Paul L. Joskow
Professor of Economics and
Management and Mitsui
Professor
Department of Economics

Mujid S. Kazimi
 Department Head and
 Professor
 Department of Nuclear
 Engineering

Chris F. Kemerer
 Douglas Drane Career
 Development Assistant
 Professor of Management
 Science
 Sloan School of
 Management

Thomas A. Kochan
 George Maverick Bunker
 Professor of Management
 and Leaders for
 Manufacturing Professor
 Sloan School of
 Management

Harilaos Koutsopoulos
 Gilbert W. Winslow Career
 Development Assistant
 Professor
 Department of Civil
 Engineering

Robert S. Langer
 Germeshausen Professor
 Department of Chemical
 Engineering

Edward Levine
 Professor
 Department of Architecture

Lawrence M. Lidsky
 Metcalf Professor of
 Engineering and the
 Liberal Arts
 Department of Nuclear
 Engineering

Richard M. Locke
 I.R.I. Career Development
 Assistant Professor of
 Management and Political
 Science
 Sloan School of
 Management

Stuart E. Madnick
 John Norris Maguire
 Professor of Information
 Technology and Leaders for
 Manufacturing Professor
 Sloan School of
 Management

David A. Mc Allester
 Esther and Harold E.
 Edgerton Assistant Professor
 of Computer Science and
 Engineering
 Department of Electrical
 Engineering and Computer
 Science

Dennis Mc Laughlin
 Gilbert W. Winslow Career
 Development Associate
 Professor
 Department of Civil
 Engineering

Jerome H. Milgram
 William I. Koch Professor
 Department of Ocean
 Engineering

Marvin L. Minsky
 Professor of Computer
 Science and Engineering
 and Toshiba Professor of
 Media Arts and Sciences
 Department of Electrical
 Engineering and Computer
 Science and Media Arts and
 Sciences Section

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

Shahryar Motakef
 Samuel C. Collins Associate
 Professor
 Department of Mechanical
 Engineering

Earl M. Murman
 Department Head and
 Professor
 Department of Aeronautics
 and Astronautics, and
 Director, Project Athena

Wayne O'Neil
 Professor and Department
 Head
 Department of Linguistics
 and Philosophy

Francesco A. Passanti
 Blackall Assistant Professor
 of History of Architecture
 Department of Architecture

Paul L. Penfield, Jr.
 Department Head and
 Professor
 Department of Electrical
 Engineering and Computer
 Science

Ronald F. Probst
 Ford Professor of
 Engineering
 Department of Mechanical
 Engineering

Michael F. Rubner
 Class of 1957 Associate
 Professor of Polymer Physics
 Department of Materials
 Science and Engineering

Charles F. Sabel
 Ford International Professor
 of Political Science
 Department of Political
 Science

Adel F. Sarofim
 Lamot du Pont Professor
 of Chemical Engineering
 Department of Chemical
 Engineering

Richard R. Schrock
 Frederick G. Keyes Professor
 of Chemistry
 Department of Chemistry

Michael S. Scott Morton
Jay W. Forrester Professor of
Management
Sloan School of
Management

Henry I. Smith
Joseph F. and Nancy P.
Keithley Professor of
Electrical Engineering
Department of Electrical
Engineering and Computer
Science

Kenneth A. Smith
Edwin R. Gilliland Professor
of Chemical Engineering in
Department of Chemical
Engineering, Associate
Provost and Vice President
for Research, and Director of
Whitaker College of Health
Sciences and Technology

Merritt R. Smith
Metcalf Professor of
Engineering and the
Liberal Arts
Program in Science,
Technology, and Society

Nam P. Suh
Ralph E. and Eloise F. Cross
Professor of Manufacturing
Department of Mechanical
Engineering

Eva Tardos
Associate Professor
Department of Mathematics

Edwin L. Thomas
Morris Cohen Professor of
Materials Science and
Engineering
Department of Materials
Science and Engineering

Karl Ulrich
Ford International Assistant
Professor of Management
Sloan School of
Management

N. Venkatraman
Richard S. Lèghorn (1939)
Management of
Technological Innovation
Career Development
Assistant Professor
Sloan School of
Management

Y. Richard Wang
Assistant Professor of
Management
Sloan School of
Management

Harry West
Carl Richard Soderberg
Assistant Professor
Department of Mechanical
Engineering

Mark S. Wrighton
Ciba-Geigy Professor of
Chemistry and Department
Head
Department of Chemistry

NEW APPOINTMENTS

Professor

Alexander A. Beilinson
Professor
Department of Mathematics

Leonidas J. Guibas
Professor of Computer
Science and Engineering
Department of Electrical
Engineering and Computer
Science

Bradford H. Hager
Professor
Department of Earth,
Atmospheric, and Planetary
Science

Ellen T. Harris
Associate Provost for the Arts
and Professor of Music
Office of the Provost

Klavs Jensen
Joseph R. Mares Professor
of Chemical Engineering
Department of Chemical
Engineering

Mario Molina
Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Theodore Postol
Professor
Program in Science,
Technology, and Society

Associate Professor

Richard C. Celotto
Associate Professor
Department of Ocean
Engineering

Irene R. Heim
Associate Professor
Department of Linguistics
and Philosophy

Thomas A. Herring
Associate Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Michael J. Hopkins
Associate Professor
Department of Mathematics

Birger Wernerfelt
Associate Professor of
Marketing
Sloan School of
Management

Assistant Professor

Keith M. Bailey
Assistant Professor and
Station Director, School of
Chemical Engineering
Practice
Department of Chemical
Engineering

David Bernstein
Assistant Professor
Department of Civil
Engineering

Victor M. Bove
Assistant Professor of Media
Technology
Media Arts and Sciences
Section

Thomas R. Chastain
Assistant Professor
Department of Architecture

Jung-Hoon Chun
Assistant Professor
Department of Mechanical
Engineering

Markus I. Flik
Assistant Professor
Department of Mechanical
Engineering

Ezra Getzler
Assistant Professor
Department of Mathematics

Thomas Paul Griffin
Assistant Professor and
Station Director, School of
Chemical Engineering
Practice
Department of Chemical
Engineering

Kenneth William Haase, Jr.
Assistant Professor
Media Arts and Sciences
Section

John C. Heaton
Assistant Professor of
Management and Economics
Sloan School of
Management

Jacqueline N. Hewitt
Assistant Professor of
Physics
Department of Physics

Qing Hu
Assistant Professor of
Electrical Engineering
Department of Electrical
Engineering and Computer
Science

Henry Jenkins III
Assistant Professor of
Literature
Literature Section

Mauricio Karchmer
Assistant Professor of
Applied Mathematics
Department of Mathematics

Lily E. Kay
Assistant Professor
Program in Science,
Technology, and Society

France Leclerc
Assistant Professor of
Management
Sloan School of
Management

Thomas Lemieux
Assistant Professor
Department of Economics

Maryellen C. Mac Donald
Assistant Professor
Department of Brain and
Cognitive Sciences

Martin Marks
Assistant Professor of Music
Music and Theater Arts
Section

Eric W. McFarland
Assistant Professor
Department of Nuclear
Engineering

Manuel Oliveria
Assistant Professor
Department of Materials
Science and Engineering

Uday Bhanu Pal
John Chipman Assistant
Professor
Department of Materials
Science and Engineering

Gregory M. Papadopoulos
Assistant Professor of
Electrical Engineering
and Computer Science
Department of Electrical
Engineering and Computer
Science

Glen D. Rennels
Thomas Cabot Assistant
Professor of Computer
Science and Engineering
Department of Electrical
Engineering and Computer
Science and Harvard-MIT
Division of Health Sciences
and Technology

Lisa B. Rofel
Assistant Professor
Anthropology/Archaeology
Program

Uri Ronnen
Assistant Professor of
Management
Sloan School of
Management

Paul Smoke
Assistant Professor of
Political Economy and
Planning
Department of Urban Studies
and Planning

Steven H. Strogatz
Assistant Professor of
Applied Mathematics
Department of Mathematics

Jean-Luc Vila
Assistant Professor of
Management
Sloan School of
Management

Paul A. Webley
Assistant Professor and
Station Director, School of
Chemical Engineering
Practice
Department of Chemical
Engineering

Hans-Conrad Zur Loye
Assistant Professor of
Chemistry
Department of Chemistry

Adjunct Professor

Ronald P. Dore
Adjunct Professor
Department of Political
Science

Joseph F. Shea
Adjunct Professor
Department of Aeronautics
and Astronautics

Visiting Professor

Boris Altshuler
Visiting Professor
Department of Physics

Prabir Basu
Visiting Professor
Department of Mechanical
Engineering

Ben S. Bernanke
Visiting Professor
Department of Economics

David H. Bradley
Visiting Professor of Writing
Writing Program

John F. Burke
Visiting Professor
Whitaker College of Health
Sciences and Technology

Charles S. Burrus
Visiting Professor
Department of Electrical
Engineering and Computer
Science

Paolo Ceccarelli
Visiting Professor
Department of Architecture

Francois Dell
Visiting Professor of
Linguistics
Department of Linguistics
and Philosophy

Amjad H. Dilawari
Visiting Professor
Department of Materials
Science and Engineering

Leopold Felsen
Visiting Professor
Department of Ocean
Engineering

Douglas Gale
Visiting Professor
Department of Economics

Michael O. Garcia
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Stanley Hart
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

George P. Hess
Visiting Professor
Department of Biology

Jun-ichi Kawata
Visiting Professor
Department of Political
Science

Moshe Livneh
Visiting Professor
Department of Civil
Engineering

Shlomo Maital
Visiting Professor
Sloan School of
Management

James E. Owers
Visiting Professor of
Accounting
Sloan School of
Management

Francisco Quesada
Visiting Professor
Media Arts and Sciences
Section

Louise A. Raphael
Visiting Professor
Department of Mathematics

Howard Rosenthal
Visiting Professor
Department of Economics

Shoji Shiba
Visiting Professor
Sloan School of
Management

Joel H. Spencer
Visiting Professor
Department of Mathematics

Jason L. Speyer
Jerome C. Hunsaker Visiting
Professor of Aeronautics and
Astronautics
Department of Aeronautics
and Astronautics

Antti Petri Talvitie
Visiting Professor
Department of Civil
Engineering

Alan Trachtenberg
Visiting Professor
Program in Science,
Technology, and Society

Lucio Ubertini
Visiting Professor
Department of Civil
Engineering

Michael Useem
Visiting Professor of
Management
Sloan School of
Management

**Visiting Associate
Professor**

Kenneth Paul Asquith
Visiting Associate Professor
Sloan School of
Management

Dennis M. Bramble
Visiting Associate Professor
Harvard-MIT Division of
Health Sciences and
Technology

Peter J. Bryanston-Cross
Visiting Associate Professor
Department of Aeronautics
and Astronautics

Amihud Dotan
Visiting Associate Professor
Sloan School of
Management

Ronald F. Ferguson
Visiting Associate Professor
Department of Urban Studies
and Planning

James Jennings
Visiting Associate Professor
Department of Political
Science

Yvon Maday
Visiting Associate Professor
Department of Mechanical
Engineering

Joachim Maier
Visiting Associate Professor
Department of Materials
Science and Engineering

Jeffrey Alan Miron
Visiting Associate Professor
Sloan School of
Management

Gary R. Strichartz
Visiting Associate Professor
Harvard-MIT Division of
Health Sciences and
Technology

Avigail Vicente
Visiting Associate Professor
Foreign Languages and
Literatures Section

Kazuo Yana
Visiting Associate Professor
Harvard-MIT Division of
Health Sciences and
Technology

**Visiting Assistant
Professor**

Padmanabhan Anandan
Visiting Assistant Professor
Media Arts and Sciences
Section

David P. Brown
Visiting Assistant Professor
of Finance
Sloan School of
Management

Ronald Edsforth
Visiting Assistant Professor
History Section

Stephen Ervin
Visiting Assistant Professor
Department of Architecture

Arthur Lewbel
Visiting Assistant Professor
of Management
Sloan School of
Management

Patricia Maes
Visiting Assistant Professor
Department of Electrical
Engineering and Computer
Science

Marcelo Breda Mourao
Visiting Assistant Professor
Department of Materials
Science and Engineering

Leslie E. Papke
Visiting Assistant Professor
of Management
Sloan School of
Management

James D. Pustejovsky
Visiting Assistant Professor
Department of Biology

Yechiel Rosenfeld
Visiting Assistant Professor
Department of Civil
Engineering

Alexandra Sotiropoulou
Visiting Assistant Professor
Department of Mechanical
Engineering

Douglas Toomey
Visiting Assistant Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Monika Totten
Visiting Assistant Professor
Foreign Languages and
Literatures Section

Bernd Widdig
Visiting Assistant Professor
Foreign Languages and
Literatures Section

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

Angela Zito
Visiting Assistant Professor
of History
History Section

ADMINISTRATION

DEATHS

Leo J. Ryan
Manager, Computer
Operations
Operations and Systems

Benjamin F. Smith
Regional Director
Alumni Association

Richard D. Woelflein
Production Manager
MIT Press

RETIREMENTS

Paul F. Barrett
Director
Physical Plant

Vincent C. Debaun
Director, Office of
Corporations and
Foundations
Vice President, Resource
Development

Ralph H. Demarco
Route Supervisor, Building
Services
Superintendent's Office

James J. Fandel
Manager, Labor Relations
Personnel Office

Alice W. Hall
Librarian
Libraries

Betty L. Hendricks
Administrative Assistant
Department of Chemistry

Bernice A. Hogan
Government Property
Administrator
Property Office

Mary J. Hovnanian
Assistant to the Director,
Military Science

John F. Howard
Staff Architect / Designer
Physical Plant

Norma Mele
House Manager
Housing

Ligija I. Neibergs
Librarian
Libraries

Frank H. Palmer
Senior Buyer / Stockroom
Supervisor
Physical Plant

Laurence W. Pickard
Manager, Grounds Services
Telecommunications
Systems

Phyllis-Lou Pulsford
Associate Director, Recruiting
Career Services and
Preprofessional Advising

Marion D. Redonnet
Administrative Assistant to
the Executive Vice President
Alumni Association

Peter R. Scott
Head, Microreproduction
Laboratory
Libraries

Paul L. Smith
Property Accountant
Property Office

James J. Sweeney
Purchasing Agent
Purchasing and Stores

Armando Tontodonato
Supervisor, Binding and
Repair
Libraries

Frank R. Wynne
Property Administrator
Lincoln Fiscal Office

RESIGNATIONS

Deena M. Anundson
Staff Accountant
Comptroller's Accounting
Office

Jennifer G. Archibald
Graduate Alumni Program
Director
Alumni Association

Mary Athanis
Coordinator, MIT / Woods
Hole Oceanographic Institute
Joint Program
Office of the Provost

Shirley K. Baker
Associate Director for Public
Services
Libraries

Carl A. Belforti
Personnel Officer
Personnel Office

Susan E. Bello
Librarian
Libraries

James F. Bixby
Senior Systems Programmer
Lincoln Fiscal Office

Ian S. Boardman
Applications Development
Programmer
Project Athena

Dennis R. Bouley
Assistant Manager,
Production Services
Operations and Systems

Sarah B. Brady
Budget Officer
Office of Financial Planning
and Management

Olga Brown
Systems Programmer
Writing Program

Timothy P. Browne
Communications Officer
Media Laboratory

Barbara J. Bruno
Contract Administrator
Office of Sponsored
Programs

Rosemary Brutico
Managing Editor, Sloan
Management Review
Sloan School of
Management

Roman J. Budzianowski
Senior Applications
Development Programmer
Project Athena

Martin H. Bunshaft
Consultant
Information Services

Anthony J. Canchola
Assistant Dean for Student
Affairs, Office of Minority
Education
Office of the Dean for
Student Affairs

Alice Carter
Administrative Officer
Center for Real Estate
Development

Peter N. Cerundolo
Manager of Corporate
Relations
Industrial Liaison Program

Marjorie Chryssostomidis
Librarian
Libraries

Jo-Anne M. Chute
Property Auditor
Property Office

Carolyn Colt
Senior Business Systems
Analyst
Administrative Systems
Development

Vickie Edwards Conrad
Analyst Programmer
Administrative Systems
Development

Marcia E. Conroy
Assistant Director for
Education and Community
Relations
Museum

Gilmore G. Cooke
Senior Electrical Engineer
Physical Plant

Edward L. Courtney
Benefits Administration
Supervisor
Personnel Office

William J. Cromie
Staff Writer / Editor
Industrial Liaison Program

Denise S. Crowe
Direct Mail Manager
MIT Press

John T. Dias
Analyst Programmer
Administrative Systems
Development

Paul J. Dworkin
Systems Programmer
Project Athena

Bethany J. Easter
Librarian
Libraries

John E. Elsabee
Technical Writer
Project Athena

Susanne H. Fairclough
Staff Writer / Editor
Alumni Association

Kevin R. Fall
Systems Programmer
Project Athena

Sandra N. Fermo
Coordinator, Senior
Executives Program
Sloan School of
Management

Nancy Ann Ferrari
Editor and Production
Manager, Communications
Office
Public Relations Services

Sarah S. Fisher
Associate Liaison Officer
Industrial Liaison Program

Jay W. Fitzgerald
Sales Manager,
Microcomputer Center
Information Services

David J. Flanagan
Systems Programmer
Project Athena

Brian Gardner
Applications Development
Programmer
Project Athena

Susan P. Gaskell
Manager, Personnel
Services and Employment
Personnel Office

Linda Gelb
Librarian
Libraries

Arthur A. Gleckler
Systems Programmer
Project Athena

Judith M. Gooch
Director of Development for
School of Science
Vice President, Resource
Development

Paul R. Goodwin
Director of Public Information
Office of the Dean for
Student Affairs

Barbara Bakal Greene
Coordinator
Office of Sponsored
Programs

Cathy Cook Greene
Librarian
Libraries

Caia C. Grisar
Consultant
Information Services

Ralph H. Griswold
Staff Electrical Engineer
Physical Plant

Robert G. Gulian
Analyst Programmer
Office of Financial Planning
and Management

Margaret Gutowski
Major Gifts Officer
Director, Major Gifts

Eduard Guzovsky
Systems Programmer
Project Athena

Evelynn Maxine Hammonds
Applications Development
Programmer
Project Athena

Pamela Hart
Administrative Officer,
Office of the Dean
School of Engineering

Debora Jo Hoard
Publicity Manager
MIT Press

Steven T. Holzinger
Consultant
Property Office

Richard O. Hope
Executive Director of the
Quality Education for
Minorities Project
Office of the Dean for
Student Affairs

Dean A. Horn
Assistant to the Director
Sea Grant College Program

Robert A. Howard
Staff Writer / Editor
Alumni Association

Barbara J. Hughes
Senior Consultant
Network Services

Watts S. Humphrey
Assistant to the Director,
Physical Plant

Anthony T. Jackson
Consultant
Information Services

Patricia Kaurouma
Associate Dean for Student
Affairs and Director, Office of
Minority Education
Office of the Dean for
Student Affairs

Cynthia D. Kowal
Financial Officer
Department of Biology

Karen L. Kramanic
Technology Licensing Officer
Technology Licensing Office

Jacobo Kredi
Manager, Electrical Services
Physical Plant

Christine F. Lamb
Manager, Journals
Department
MIT Press

John W. Larson
Associate Director
National Campaign Office

Irene S. Leamon
Analyst Programmer
Administrative Systems
Development

Michael C. Leonard
Route Supervisor, Grounds
Services
Physical Plant

June A. Lipnoski
Manager of Information
Service
Industrial Liaison Program

Bernard R. Lougee
Senior Technical Writer
Administrative Systems
Development

Dianne F. Maloney
Purchasing Agent
Office of Laboratory Supplies

Kathleen Marquis
Librarian
Libraries

Donna A. Martel
Graduate Student
Administrator
Department of Earth,
Atmospheric, and Planetary
Sciences

Sharon L. Mc Carrell
 Librarian
 Libraries

Karen P. Mc Carty
 Operations and
 Administration Manager
 Telecommunications
 Systems

Maurice Mc Dermott
 Analyst Programmer
 Administrative Systems
 Development

June R. Milligan
 Property Auditor
 Property Office

Nancye J. Mims
 Special Assistant for Legal
 Affairs
 Vice President, Resource
 Development

Tobin H. Mintz
 Applications Development
 Programmer
 Project Athena

Jonathan G. Monsarrat
 Technical Writer
 Project Athena

Steven T. Nalesnik
 Analyst Programmer
 Student Financial Aid Office

Carol Ng-Lee
 Assistant to the Director,
 Office of Minority Education
 Office of the Dean for
 Student Affairs

Mary K. Norman
 Associate Director, Alumni
 Fund
 Alumni Association

James E. O'Connell
 Coordinator, Facilities
 Maintenance
 Division of Comparative
 Medicine

Lisa A. Oteri
 Assistant Director
 Student Financial Aid Office

Carol A. Peterson
 Circulation Manager, Sloan
 Management Review
 Sloan School of
 Management

Lisa C. Peterson
 Assistant Director
 Office of Campaign Systems

Jan Popiel
 Technical Supervisor
 Architecture and Strategic
 Technology

Rosemary E. Previte
 Editor
 MIT Press

Laura A. Radin
 Editor
 MIT Press

Gigi Reinheimer
 Assistant Marketing Manager
 MIT Press

Elizabeth Rigby
 Research Assistant, Quality
 Education for Minorities
 Project
 Office of the Dean for
 Student Affairs

Brenda R. Robertson
 Personnel Administrator
 Department of Physics

Tracy L. Robinson
 Director of Research, Quality
 Education for Minorities
 Project
 Office of the Dean for
 Student Affairs

Maria Rodrigues
 Assistant to the Director,
 Office of Minority Education
 Office of the Dean for
 Student Affairs

Lucille M. Rosa
 Associate Head Librarian
 Libraries

David M. Rosenberg
 Systems Programmer
 Operations and Systems

Katherine E. Sammakia
 Librarian
 Libraries

Jan A. Scott
 Area Administrator
 Sloan School of
 Management

Chester T. Seymour
 Auditor
 Audit Division

Michael S. Shanzer
 Systems Programmer
 Project Athena

Julie Simms
 Graphic Designer
 MIT Press

William H. Simpson
 Technical Supervisor
 Lincoln Fiscal Office

Betsy Joan Singelais
 Benefits Administration
 Supervisor
 Personnel Office

David A. Smith
 Supervisor, Circulation
 Services
 Libraries

Kevin S. Smith
 Systems Programmer
 Operations and Systems

Jacqueline A. Stewart
 Manager of User Services,
 Applications Development,
 and Visual Courseware
 Project Athena

Tali Tamir
Admissions Counselor
Admissions Office

Deborah J. Tarboton
Librarian
Libraries

Abbas Tayaran
Purchasing Administrator,
Microcomputer Center
Information Services

William R. Tibbs
Planning Officer
Planning Office

Giancarlo Trevisan
Applications Development
Programmer
Department of Electrical
Engineering and Computer
Science

Mark A. J. Valentine
Consultant
Information Services

Mark A. Vargas
Librarian
Libraries

Shelley L. Weiner
Administrative Assistant
Department of Civil
Engineering

Robert E. Weirnerman
Admissions Counselor
Admissions Office

Lynda B. Wellen
Auditor
Audit Division

Gary T. Welsh
Senior Consultant
Information Services

Stephen R. Williams
Technology Licensing Officer
Technology Licensing Office

Mark Wilson
Communications Manager
Public Relations Services

Elizabeth M. Winiarz
Librarian
Libraries

Teressa M. Wittig
Librarian
Libraries

Keva M. Wright
Conference and Meeting
Coordinator
Office of the Dean for
Student Affairs

Kenneth C. Zolot
Senior Systems Programmer
Project Athena

NEW APPOINTMENTS

Debra Gross Aczel
Program Administrator,
Integrated Studies Program
School of Humanities and
Social Science

Patricia F. Ahern
Librarian
Libraries

Michelle M. Aimone
Technical Writer
Comptroller's Accounting
Office

Linda M. Antone
Operations Coordinator
Network Services

Katherine F. Arnoldi
Senior Editor
MIT Press

Marian E. Bach
Life Income Funds
Administrator
Treasurer's Office

Astrid C. Baehrecke
Direct Mail Manager
MIT Press

Marion I. Bagley
Purchasing Administrator,
Microcomputer Center
Information Services

Richard P. Basch
Systems Programmer
Project Athena

Claire Benoit
Administrative Assistant
Department of Civil
Engineering

F. Michele Berrie
Applications Development
Programmer
Project Athena

Richard A. Bjorkman
Assistant to the Director
Lowell Institute School

Beverley (Penny) Blaisdell
Director of Information
Services
Vice President for
Information Systems

Neil J. Blaisdell
Assistant Marketing Manager
MIT Press

John Boguslawski
Systems Programmer
Operations and Systems

Nikki J. Borman
Financial Administrator
Technology Licensing Office

Dorothy L. Bowe
Consultant
Project Athena

Alan Bowers
Inventory Accountant,
Microcomputer Center
Information Services

Herbert M. Brody
Staff Writer / Senior Editor
Alumni Association

Stephanie Bromander
Assistant Business Officer
Office of Laboratory Supplies

Madeline H. Brown
Acquisitions Coordinator
MIT Press

Maria S. Byerly
Associate Liaison Officer
Industrial Liaison Program

Louise E. Carella
Administrative Assistant
Vice President, Resource
Development

Brent M. Carlton
Financial Analyst
Sloan School of
Management

Allen J. Cavicchi
Staff Mechanical Engineer
Physical Plant

Alan Bruce Chaiken
Senior Business Systems
Analyst
Administrative Systems
Development

Jennifer R. Chisholm
Administrative Assistant,
Office of the Dean
School of Engineering

Ekaterini L. Christidis
Analyst Programmer
Purchasing and Stores

Marjorie Chrystostomidis
Librarian
Libraries

Gilmore G. Cooke
Senior Electrical Engineer
Physical Plant

Thomas B. Cosgrove, Jr.
Property Administrator
Lincoln Fiscal Office

Christopher R. Craig
Systems Programmer
Project Athena

Sylvia R. Crone
Administrator, MIT Alumni
Center of New York
Alumni Association

Frances C. Cummings
Assistant to the Publisher
Sloan School of
Management

Janet M. Daly
Information Officer
Project Athena

Robert M. Damian
Assistant Auditor
Audit Division

Daniel J. Dangler
Subcontract Administrator
Purchasing Field Office

Pamela C. Daveta
Administrative Coordinator,
MIT Women's League
Office of the President

Ruth T. Davis
Editor and Production
Manager, Communications
Office
Public Relations Services

Judith F. De Courcey
Benefits Administration
Supervisor
Personnel Office

Lawrence Dean
Senior Project Manager
Operations and Systems

Jacques Victor Dejean
Systems Programmer
Operations and Systems

Deborah A. Devine
Program Coordinator,
Advanced Study Programs
Center for Advanced
Engineering Study

Anthony P. Dipesa, Jr.
Technical Supervisor
Office of Facilities
Management Systems

Tammy L. Doyle
Buyer and Stockroom
Supervisor
Physical Plant

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

Marsha Edmunds
Assistant Manager,
Sustaining Fellows and
Special Events
National Campaign Office

Wendy M. Elliott
Industrial Liaison Officer
Industrial Liaison Program

Sarah J. Eusden
Assistant for Government and
Community Relations
Office of the President

Bernita F. Faust
House Manager
Housing

Sharalee M. Field
Assistant Planning Officer
Planning Office

Craig Alan Fields
Applications Development
Programmer
Project Athena

Janet Fisher
Manager, Journals
Department
MIT Press

Barbara Frank
Administrative Assistant to
the Medical Director
Medical Department

John J. Fucillo
Operations Assistant
Department of Biology

Kathryn L. Gandek
Senior Research Analyst
Vice President, Resource
Development

John M. Gannon
Coordinator, Facilities
Maintenance
Division of Comparative
Medicine

Marlene Gast-Alexander
Technical Writer
Administrative Systems
Development

John William Gettens
Systems Programmer
Project Athena

Joyce Gilardi
Assistant to the Director,
Military Science

George J. Gillis
Route Supervisor, Building
Services
Physical Plant

Allison Carol Green
Associate Editor, Sloan
Management Review
Sloan School of
Management

Eduard Guzovsky
Systems Programmer
Project Athena

Nancy A. Hannula
Purchasing Agent
Office of Laboratory Supplies

Joseph L. Hardmond
Analyst Programmer
Administrative Systems
Development

Maria I. Hecht
Publications Coordinator
Office of the Summer
Session

Frances Helmstadter
Head, International Scholars
Office
Public Relations Services

Beatrix A. Henize
Coordinator of Corporate
Research and Marketing
Industrial Liaison Program

Elizabeth Hesse
Librarian
Libraries

Bailey E. Hewit
House Manager
Housing

Jafar Hosseinzadeh
Consultant
Information Services

Anne M. Hubbard
Senior Designer / Production
Manager
Public Relations Services

Dena M. Hutto
Librarian
Libraries

Barbara L. Ives
Supervisor, Technical
Processing Services
Libraries

M. Susan Jones
Consultant
Information Services

Steven M. Jones
Consultant
Information Services

Jonathan Kamens
Systems Programmer
Project Athena

Anna M. Koch
Assistant Archivist
Libraries

Laurence F. Koolkin
Manager of User Services
Project Athena

Judith Ann Kritzman
Senior Applications
Coordinator
Office of Facilities
Management Systems

Larissa Kushkuley
Analyst Programmer
Administrative Systems
Development

Michael G. Larivee
Consultant
Project Athena

John D. Larkin
Property Auditor
Property Office

Douglas J. Le Vie
Staff Accountant
Comptroller's Accounting
Office

Jeannet Leendertse
Designer
MIT Press

Kim C. LePage
Area Administrator
Sloan School of
Management

Bruce Lewis
Applications Development
Programmer
Project Athena

Robert J. Lewis
Manager, Labor Relations
Personnel Office

David M. Libby
Coordinator, General Gifts
Solicitation / Alumni Fund
Alumni Association

Ching-Chuan Liu
Consultant
Project Athena

Laura Costa Lucas
Assistant to the Manager of
Systems
Physical Plant

Judith A. Mangan
Assistant Director
Director, Major Gifts

Michael F. Mc Carthy
Property Auditor
Property Office

Steven C. Mc Cluskey
Purchasing Agent
Purchasing and Stores

Sarah Mc Conville
Publicity Manager
MIT Press

Barbara G. Mc Donald
Administrative Assistant
Office of Campaign Systems

Margaret M. Mc Grath
Supervisor, Purchasing
Support Services Group
Purchasing and Stores

Shawn F. Mc Kay
Software / Hardware Analyst
Department of Electrical
Engineering and Computer
Science

Rebecca S. Mc Leod
Journals Advertising and
Exhibits Manager
MIT Press

Brian Melanson
Systems Programmer
Operations and Systems

H. Collins Mikesell, Jr.
Analyst Programmer
Student Financial Aid Office

Branger Miller
Major Gifts Officer
Director, Major Gifts

Sandra H. Minkinen
Senior Editor
MIT Press

Paul M. Mitchell
Route Supervisor, Building
Services
Physical Plant

Christine M. Mleynek
Senior Research Analyst
Vice President, Resource
Development

Jonathan G. Monsarrat
Technical Writer
Project Athena

Phillips B. Moore
Director of Operations and
Administration
Treasurer's Office

Ayida Mthembu
Assistant Dean for Student
Affairs, Student Assistant
Services
Office of the Dean for
Student Affairs

Leslie A. Mulford
Budget Officer
Office of Financial Planning
and Management

Pablo Navarro-Rivera
Assistant Dean for Student
Affairs and Assistant Director,
Office of Minority Education
Office of the Dean for
Student Affairs

Carol Ng-Lee
Assistant to the Director,
Office of Minority Education
Office of the Dean for
Student Affairs

Donna J. O'Neill
Staff Accountant
Libraries

Cynthia S. Olson
Supervisor, Records Office
Personnel Office

Harold Pakulat
Consultant
Operations and Systems

Gary R. Panaro
Assistant Director for
Administration and Finance
Vice President for
Information Systems

James A. Paterson
Senior Research Analyst
Office of Development
Services

Ezra Peisach
Systems Programmer
Project Athena

Joan Perkins
Documentation Manager
Administrative Systems
Development

Susan R. Personette
Senior Staff Architect
Physical Plant

Lucille B. Piazza
Assistant Contract
Administrator
Office of Sponsored
Programs

J. Tracy Pierce
Producer, Special Programs
Center for Advanced
Engineering Study

Judy Jackson Pitts
Assistant Dean for Student
Affairs and Assistant Director,
Office of Minority Education
Office of the Dean for
Student Affairs

Joanna M. Poole
Assistant Acquisition Editor
MIT Press

Lori Pressman
Technology Licensing Officer
Technology Licensing Office

Rosemary E. Previte
Editor
MIT Press

Robert N. Principato
Associate Registrar and
Manager, Student
Information Systems
Office of the Registrar

Ellen F. Quaadgras
Systems Analyst
Sloan School of
Management

Lisa A. Quackenbush
Staff Writer / Editor
Leaders for Manufacturing
Program

Robert T. Ramsay, Jr.
House Manager
Housing

Lorraine J. Rappaport
Facilities Analyst
Telecommunications
Systems

James N. Rees, Jr.
Consultant
Project Athena

Rebecca Lynn Robins
Supervisor, Technical
Processing Services
Libraries

Peter Roden
Manager of Systems and
Operations
Project Athena

Alexander Roderigues
Analyst Programmer
Alumni Association

Iria J. Romano
Assistant to the Registrar
Registrar's Office

David M. Rosenberg
Systems Programmer
Operations and Systems

Laura G. Royer
Supervisor, Circulation
Services
Libraries

Anne Salemme
Systems Programmer
Operations and Systems

Jennie S. Sandberg
Librarian
Libraries

Naomi B. Schmidt
Manager of Educational
Initiatives
Project Athena

Mark V. Scott
Librarian
Libraries

G. Christine Sherratt
Librarian
Libraries

Denis W. Shield
Applications Programmer
Lincoln Fiscal Office

Kay Sibary
Senior Business Systems
Analyst
Administrative Systems
Development

Betsy Joan Singelais
Benefits Administration
Supervisor
Personnel Office

Richard J. Sirois
Supervisor, Mechanical
Services
Physical Plant

Pamela Slot
Purchasing Coordinator
Division of Comparative
Medicine

Jerry W. Smith
Assistant Operations
Manager
Telecommunications
Systems

Kevin S. Smith
Systems Programmer
Operations and Systems

Gail-Lenora Staton
Assistant to the Director,
Office of Minority Education
Office of the Dean for
Student Affairs

Beverly S. Stohl
Graduate Student
Administrator
Department of Economics

Susan Stone
Benefits Administration
Supervisor
Personnel Office

Young Liem Sul
Systems Programmer
Operations and Systems

Jonathan A. Sweemer
Venture Capital Officer
Treasurer's Office

Tali Tamir
Admissions Counselor
Admissions Office

Ronald A. Thomann
Associate Director of Major
Gifts
Director, Major Gifts

Constance Turnburke
Administrative Assistant
Department of Chemical
Engineering

Lucien W. Van Elsen
Consultant
Project Athena

Christopher J. Van Haren
Applications Development
Programmer
Project Athena

Melissa J. Vaughn
Production Editor
MIT Press

Paul Clinton Vermouth, Jr.
Librarian
Libraries

M. Jennifer Walsh
Personnel Administrator
Department of Physics

Sue-Yi Wang
Assistant to the Bursar,
Student Services
Office of the Bursar

Robert A. Warshow
Consultant
Information Services

Daniel J. Watt
Manager, Class Giving
Alumni Association

Michael A. Webster
Applications Development
Programmer
Project Athena

Patrick L. Weygint
Publications Manager
Center for Advanced
Engineering Study

Leslie A. Whitaker
Director of the
Undergraduate Laboratory
Department of Chemistry

Ann B. Whiteside
Supervisor, Technical
Processing Services
Libraries

Rae Jean N. Wiggins
Librarian
Libraries

Stephen R. Williams
Technology Licensing Officer
Technology Licensing Office

Susannah B. Wolfson
Senior Research Analyst
Vice President, Resource
Development

Esther Yanow
Senior Technical Writer
Administrative Systems
Development

Patricia Yingling
Technical Writer
Administrative Systems
Development

Imelda Zepf
Staff Accountant
Comptroller's Accounting
Office

Stephen H. Zimmerman
Auditor
Audit Division

CHANGES OF APPOINTMENT

Maija K. Ahlquist
Administrative Officer
Department of Biology

Miriam K. Ahmed
Designer
MIT Press

Katherine K. Allen
Assistant to the Vice
President
Vice President for Information
Systems

China Altman
Director of Arts
Communication
Office of the Arts

Beth Anderson
Consulting Manager
Project Athena

Leah Anderson
Administrative Officer
Department of Political
Science

T. Gregory Anderson
Associate Director for
Systems and Planning
Libraries

Z. Dana Andrus
Senior Editor
MIT Press

Jill A. Appel
Senior Consultant
Network Services

Anne E. Armitage
Associate Director, Recruiting
Career Services and
Preprofessional Advising

Catherine R. Avril
Manager of External
Relations
Project Athena

Joseph E. Baclawski
Senior Industrial Liaison
Officer
Industrial Liaison Program

Dennis Baron
Senior Project Manager
Network Services

Paul Max Bethge
Senior Editor
MIT Press

Harmon E. Brammer
Director
Physical Plant

Gerald D. Burke
Technical Supervisor
Network Services

David E. Burnett
Accounting Officer
Comptroller's Accounting
Office

Sarah M. Carothers
Senior District Director
National Campaign Office

Joy J. Carrigan
Senior District Director
National Campaign Office

Estelle M. Cashman
Manager, Campus Visits
Program
National Campaign Office

Nancy E. Cavanagh
Administrative Officer
Music and Theater Arts
Section

Marie C. Cedrone
Contract Administrator
Office of Sponsored
Programs

Sarah W. Cliffe
Managing Editor, Sloan
Management Review
Sloan School of
Management

Allison P. Cocuzzo
Administrative Officer
Center for Advanced
Engineering Study

Maria C. Correia
Supervisor, Customer
Support
Operations and Systems

Joanne Costello
Manager of User Services
Network Services

Phyllis Crierie
Consultant
Information Services

Paula B. Cronin
Publisher
Sloan School of
Management

Steve L. Csipke
Editorial Supervisor
Administrative Systems
Development

Kevin M. Cunningham
Senior Technical Writer
Project Athena

Mark L. Curby
Consultant
Network Services

Stephen Daley
Sergeant
Campus Police

Benjamin H. Davis
Manager of Visual
Computing Group
Project Athena

Frances Davis
Fiscal Officer
Telecommunications
Systems

Peter J. Delaney
Manager, Operations and
Administration
Telecommunications
Systems

June E. Desmarais-Mc Caull
Assistant Journals Manager
MIT Press

Joseph M. Dhosi
Senior Administrative Officer
Department of Materials
Science and Engineering

Norman Doelling
Executive Officer / Assistant
Director for Advisory Services
and Education
Sea Grant College Program

Alfred R. Doig, Jr.
Assistant Dean for Resource
Development
School of Engineering

Eileen G. Dorschner
Librarian
Libraries

Teresa Ann Ehling
Acquisition Editor
MIT Press

Kenneth Feldman
Consultant
Information Services

David S. Ferriero
Associate Director for Public
Services
Libraries

Patricia J. Finocchio
Manager of Systems
Property Office

Janet E. Fischer
Assistant to the Bursar,
Student Services
Office of the Bursar

Mary Pat Fitzgerald
Assistant to the President of
the Whitaker Health Sciences
Fund
Office of the President

Robyn L. Fizz
Marketing Communications
Coordinator
Information Services

Kathleen M. Flynn
Systems Coordinator
Personnel Office

John J. Foley
Assistant Director for
Administration
Physical Plant

Alexandra Folger
Consultant
Information Services

Dana Friis-Hansen
Curator
List Visual Arts Center

Richard J. Frye
Manager
Graphic Arts Purchasing
Office

Kathryn L. Gandek
Assistant Director
Office of Development
Services

Elizabeth A. Garvin
Program Director, Major
Reunion Giving
Alumni Association

Deborah A. Gibson
Assistant Accounting Officer
Comptroller's Accounting
Office

Norma M. Gicka
Accounting Analyst
Sloan School of
Management

Dianne M. Goldin
Senior District Director
National Campaign Office

Caia C. Grisar
Consultant
Information Services

Robert G. Gulian
Analyst Programmer
Office of Financial Planning
and Management

Mary J. Gulino
Manager, Production and
Systems Support
Office of Campaign Systems

Jeffrey C. Harrington
Senior Systems Programmer
Operations and Systems

V. Judson Harward
Applications Development
Programmer
Project Athena

Richard J. Heavern
Technical Supervisor
Lincoln Fiscal Office

Kenneth L. Hewitt
Senior Personnel Officer
Personnel Office

Lucinda M. Hill
Assistant Director of the
Master's Program and
Director of Master's Alumni
Relations
Sloan School of
Management

Richard M. Hill
Assistant Dean for Financial
Administration
Dean of Science

Gloria A. Hodgens
Program Director, Young
Alumni Programs
Alumni Association

Thomas S. Hoole
Business Officer
Office of Laboratory Supplies

Barbara J. Hughes
Senior Consultant
Network Services

John B. Jacoby
Associate Director
Office of Development
Services

Diane Jaroch
Design Manager
MIT Press

Rita M. Jellison
Assistant to the Director
Office of Campaign Systems

Scott Jensen
Systems Programmer
Industrial Liaison Program

David G. Kalendarian
Systems Programmer
Operations and Systems

Sheila M. Kanode
Administrative Officer,
Office of the Dean
School of Engineering

Stephen R. Kellogg
Associate Director of Stores
Office of Laboratory Supplies

Martin J. Kelly
Senior Staff Accountant
Comptroller's Accounting
Office

Timothy W. Keohan
Assistant Director for
Automated Systems
Office of Financial Planning
and Management

Sassan Khoubyari
Analyst Programmer
Office of Facilities
Management Systems

Anita Killian
 Administrator, Student Office
 Department of Earth,
 Atmospheric, and
 Planetary Sciences

Katherine G. (Katy) Kline
 Director
 List Visual Arts Center

Alison Grice Knott
 Manager of Information
 Systems
 Medical Department

Marilyn K. Kuhar
 Associate Director
 National Campaign Office

Sandra Wells Ladd
 Senior Analyst Programmer
 Administrative Systems
 Development

Carmen F. Lahan
 Accounting Officer
 Treasurer's Office

David F. Lambert
 Manager, Computer
 Operations
 Operations and Systems

Theresa M. Lamoureux
 Production Manager
 MIT Press

Joanne W. Larrabee
 Manager of Microcomputing
 Resources
 Information Services

John W. Larson
 Associate Director
 National Campaign Office

Florent Lebongo
 Assistant to the Bursar,
 Student Services
 Office of the Bursar

Wai-Ming Li
 Analyst Programmer
 Office of Financial Planning
 and Management

Lu Liu
 Analyst Programmer
 Office of Facilities
 Management Systems

David L. Lundberg
 Assistant Dean for
 Development, School of
 Humanities and Social
 Science
 Vice President, Resource
 Development

Elizabeth A. Lynds
 Analyst Programmer
 Comptroller's Accounting
 Office

E-Ping Lucia Ma
 Analyst Programmer
 Office of Financial Planning
 and Management

Meg Manderson
 Summer Session Office
 Finance Officer / HASS
 Administrator
 Office of the Summer
 Session

Judith E. Mason
 Coordinator, Senior
 Executives Program
 Sloan School of
 Management

Irene Mazor
 Supervisor, Circulation
 Services
 Libraries

Francis H. Mc Groy
 Associate Treasurer and
 Director, Capital Gifts and
 Legal Affairs
 Treasurer's Office

Carol Ann Mc Intire
 Administrative Assistant
 Department of Civil
 Engineering

Diane E. Mc Laughlin
 Assistant Dean for
 Administration
 School of Architecture and
 Planning

Celia W. Metcalf
 Director, Design Services
 Public Relations Services

Betsy Millard
 Senior District Director
 National Campaign Office

David L. Millay
 Senior Manager, Mechanical
 Services and Operations
 Physical Plant

Kimberly Miner
 Circulation Manager, Sloan
 Management Review
 Sloan School of
 Management

Stephen P. Miscowski
 Manager, Electrical Services
 Physical Plant

Thomas R. Moebus
 Director
 Industrial Liaison Program

Roger Moore
 Superintendent of Utilities
 and Engineering
 Physical Plant

Errol W. Morrison
 Facilities Analyst
 Telecommunications
 Systems

Maria S. Muollo
 Assistant Director
 Office of the Summer
 Session

Rose M. Needham
Assistant Manager, Campus
Activities Complex
Physical Plant

Gail Garfield Neuman
Consultant
Information Services

Junco N. Norton
Budget Officer
Office of Financial Planning
and Management

Linda Salza Olson
Coordinator, Claims and
Member Services,
M I T Health Plan
Medical Department

Thomas J. Owens
Head, Library Systems Office
Libraries

Cassandra N. Page
Manager, Sustaining Fellows
and Special Events
National Campaign Office

Mark A. Palmgren
Director of the Council for
the Arts
Office of the Arts

Jeffrey D. Pankin
Consultant
Information Services

Firooz Partovi
Senior Consultant
Office of the Provost

Barbara A. Peterson
Program Director, Student
Programs
Alumni Association

Philip L. Philips
Senior Accounting Officer
Lincoln Fiscal Office

Judy Jackson Pitts
Associate Dean for Student
Affairs and Director, Office of
Minority Education
Office of the Dean for
Student Affairs

Charlene M. Placido
Assistant to the Vice
President for Research
Office of the Provost

Dennis L. Porch III
Assistant to the Department
Head
Department of Mathematics

Laura L. Quinn
Major Gifts Officer
Major Gifts, Director

David P. Ralston
Systems Programmer
Operations and Systems

Laxmi J. Rao
Technical Supervisor
Administrative Systems
Development

Pamela Ravesi
Administrative Assistant,
Vendor Services
Information Services

Lee S. Ridgway
Senior Technical Writer
Information Services

Barry C. Roberts
General Manager
Office of Laboratory Supplies

Beverly A. Robinson
Financial Administrator
Telecommunications
Systems

Jon A. Rochlis
Systems Programmer
Network Services

Peter Roden
Manager of Systems &
Operations
Project Athena

Cara S. Rodgers
Applications Coordinator
Office of Facilities
Management Systems

Mark A. Rosenstein
Systems Programmer
Operations and Systems

Peter A. Rossetti
Shift Supervisor, Building
Services
Physical Plant

Susan Cronin Ruderman
Assistant Director
Office of Campaign Systems

James T. Salini
Senior Staff Accountant
Physical Plant

Katherine E. Sammakia
Librarian
Libraries

Michael Sampson
Consultant
Network Services

Marco Sarmiento
Senior Analyst Programmer
Administrative Systems
Development

Laura M. Scarlett
Assistant to the Managing
Director, Alumni Activities
Alumni Association

Jeffrey I. Schiller
Manager of Systems and
Operations
Network Services

Evelyn Schlüsselberg
Applications Development
Programmer
Project Athena

Naomi B. Schmidt
Manager of Educational
Initiatives
Project Athena

Ronni M. Schwartz
Administrator, M I T / Woods
Hole Oceanographic Institute
Joint Program
Office of the Provost

Marjorie E. Sciulli
Senior Staff Accountant
Comptroller's Accounting
Office

Jolanda Scott
Assistant to the Bursar -
Control and Accounting
Office of the Bursar

Brian S. Shannon
Transmission Manager
Telecommunications
Systems

Diane J. Shea
Manager of Stores
Purchasing
Office of Laboratory Supplies

Sharon Potter Shea
Staff Accountant
Office of the Dean for
Student Affairs

Frank J. Silva, Jr.
Assistant Accounting Officer
Comptroller's Accounting
Office

E. Donald Smith, Jr.
Supervisor, Circulation
Services
Libraries

Jeffrey Robert Solof
Manager, Microcomputer
Center
Information Services

Kambiz Soroushian
Applications Development
Programmer
Project Athena

Janice T. Steingesser
Assistant Director
Office of Development
Services

Wendy B. Stone
Assistant Director,
Information Systems and
Budget
Physical Plant

Ronald P. Suduiko
Assistant to the President for
Government and Community
Relations
Office of the President

Virginia Meredith Thomas
District Director
National Campaign Office

Edith A. Thompson
Accounting Officer
Comptroller's Accounting
Office

Elizabeth A. Thomson
Staff Writer / Editor
Public Relations Services

Scott Thorne
Analyst Programmer
Network Services

Susan R. Tibbetts
Senior Technical Writer
Information Services

Theresa A. Tobin
Associate Head Librarian
Libraries

Anthony Turano
Senior Industrial Liaison
Officer
Industrial Liaison Program

Wayne T. Turner
Accounting Officer
Comptroller's Accounting
Office

Christopher J. Van Haren
Applications Development
Programmer
Project Athena

David L. Verrill
Senior Industrial Liaison
Officer
Industrial Liaison Program

Sally D. Vlamis
Technical Writer
Administrative Systems
Development

Katherine Ware
Financial Administrator
Department of Earth
Atmospheric, and Planetary
Sciences

Sharon D. Warne
Graphics Production
Coordinator
M I T Press

Michael A. Webster
Applications Development
Programmer
Project Athena

Cynthia C. Westhoff
Senior Analyst Programmer
Comptroller's Accounting
Office

Lillian H. Whelpley
Advisor to International
Scholars
Public Relations Services

Randall Wayne Winchester
Facilities Analyst
Telecommunications
Systems

Kenneth H. Wolff
Personnel Officer
Personnel Office

Randall Wright
Senior Industrial Liaison
Officer
Industrial Liaison Program

Kenneth C. Zolot
Senior Systems Programmer
Project Athena

PROVOST

This is my fifth and final report as Provost and I wish to devote my remarks to thanking those individuals who have been so helpful to me both professionally and personally.

I begin by thanking Paul Gray for giving me the opportunity to serve the Institute as Provost. The Institute is an intellectually rich place and thus it has been most exciting to be its chief academic officer. But beyond this professional debt to Paul, I have a vast personal debt for the friendship and support he has extended to me.

The members of Academic Council have all been loyal, capable and, happily, frequently humorous in discharging their duties under my leadership [a vastly overused word] and I am grateful to this remarkably talented group. Several members of Academic Council are now numbered among my closest friends and this is another important benefit from serving as Provost.

I especially mention my gratitude to the contributions of the staff of the Office of the Provost. All will acknowledge that while there may have been some [misguided] criticisms of the man, there has never been a whisper of criticism about any of the splendid individuals who have, perhaps suprisingly, been willing to serve with him in the Office. Doreen Morris is a central figure of the Institute and of particular importance to its future financial health. I am grateful to my secretaries Marge Tyler and, earlier, Kathleen Perkins for both their support and patience.

What does the future have in store? There are many individuals who I am sure would make excellent Provosts for MIT. More importantly, I believe that MIT is entering a period of very significant intellectual advance in both education and research. Moreover, unlike many, I believe the resources will be available to pursue these opportunities but it is necessary to improve our capacity to make choices among competing worthy alternatives.

I urge my faculty colleagues to join me in giving every assistance to the next Provost in pursuing these opportunities.

JOHN M. DEUTCH

Libraries

The past year has been an extremely active and exciting period for the MIT Libraries with a number of major programs and projects fully underway and others in earlier stages of development or in a planning mode. The report that follows describes a wide range of activities, some of which involve a small set of staff from one library department or a group of departments, while others require the engagement of large numbers of librarians, other professional staff, and support staff from throughout the system. All that has been and continues to be successful in the MIT Libraries results in large measure because of the skill and dedication of the staff and their ability to meet new challenges and new demands for service. Success is also a function of the degree to which the organization functions as a single entity with a common view of its purpose within the Institute and in the scholarly world in which MIT functions. Immediately following are summaries of the work of four library departments: Rotch Library, Acquisitions, Dewey Library, and Systems, that illustrate the scope and complexity of what is involved in the operation of a major research library. The report continues with a general summary of the year's events.

ROTCH LIBRARY OF ARCHITECTURE AND PLANNING

Last year saw the beginning of construction of the long awaited addition to Rotch Library. In the 13 months since ground-breaking (May, 1989) a remarkable new six story building has emerged. The unique structural design of the building coupled with its dramatic use of aluminum and glass, has already attracted a great deal of interest and attention. The move of collections and services into the new building began in early July and renovation of the existing library is underway. Completion of the entire project is anticipated in October, 1990.

The building process involved every section of the School of Architecture and Planning, every department of the Libraries, every unit of Physical Plant, neighbors in other MIT buildings, the City of Cambridge, and the Commonwealth of Massachusetts. The teamwork of the architects - Schwartz/Silver, and the contractor - Macomber Construction Company, combined with the contributions of the Institute and Libraries' staffs, managed to keep the construction schedule on target while permitting the library to continue to function without major interruption. Some examples:

- Circulation of library materials increased three percent over the previous year. Course reserves expanded by 11 percent, led by extensive reading assignments for new courses in art and architectural history.
- A joint project team of Rotch technical services staff and the Catalogue Department undertook a reclassification project for Dewey Decimal titles in the limited access and folio collections.
- Students in the Center for Real Estate Development program benefited from targeted information services: increased acquisitions, subsidized online searching for thesis research, bibliographic guides, and a class section on library research methods.
- The transition to electronic information continued with the installation of three CD-ROM products: Art Index, Supermap (a census data and mapping resource using optical disk), and Sweetsearch, the online version of Sweet's architectural catalogs.

- Rotch Visual Collections developed a new and greatly improved sign-up system for visual reserves. Thirty percent of the year's acquisitions -- 8,000 slides -- were processed for specific teaching and research needs of new art and architectural history courses.
- The staff, through a number of task groups and ad-hoc committees, worked on a variety of expansion related issues including space planning, furnishings, and telecommunications; moving the collections; setting up temporary offices and service stations; running staff meetings; planning to handle emergencies and disasters of fire and water; reorganizing internal delivery routes; developing electronic reference services; and communicating construction news to the library's user community.
- Contributions from other parts of the system included assistance in planning; telecommunications design; liaison with book and furniture movers; preservation; records management; electronic reference; and retrospective conversion. Assistance and support came from every part of the Libraries.

ACQUISITIONS DEPARTMENT

Improved service to users of the MIT Libraries is the focus of all activities within the library system. In addition to continued efforts to provide materials in a timely and efficient manner, the special focus in Acquisitions last year was on streamlining procedures. The two most dramatic changes took place in Serials Receipts with the creation of serial commitment databases and implementation of decentralized periodical check-in.

During the summer of 1989, work was completed on the development of a locally controlled serials commitment database replacing a batch system used for many years and which was outside of the Libraries' purview. The new system provides the flexibility to make changes at any time and eliminates the need for input forms. It also allows staff to sort data in a variety of ways and to produce customized reports. In addition to the basic database that includes order number, fund, type of material, title and vendor, there are two other files. The Vendor File links the vendor code to full address and account information. The Payments Database provides both a complete payment record and historical information on serial prices.

In January, 1990, the transition from centralized to decentralized periodical check-in was begun. In preparation, address changes were sent to vendors and publishers and staff committees planned for the transfer of work in the several divisional and branch libraries. While the impact of the change is still being felt in the public service units, there is every indication that the overall effect will be beneficial, not the least of which was the transfer of two positions from Serials to Retrospective Conversion.

Other accomplishments of note in the Acquisitions Department include:

- The exchange and gifts operation was reorganized with exchanges assigned to Serials Receipts and with the transfer of responsibility for MIT publications to the Gifts Librarian.
- Four sales of duplicates and unneeded items were held for the MIT community with net income of almost \$8,000. Sales to dealers and collectors netted an additional \$5,000.

- Work was completed on the U.S. Government Documents Selection Decision List that shows the location of all items retained by the MIT Libraries as a selective depository of government publications.
- There is a continuing effort to reduce the amount of order form typing for categories of material like MIT publications and monographs in series.

DEWEY LIBRARY

There were significant increases in a number of aspects of public services in the Dewey Library last year. A few examples:

	<u>FY90</u>	<u>FY89</u>	<u>% Change</u>
Presentations to groups	24	12	+ 100%
Number of people reached in group presentations	388	349	+ 11%
Quick reference searches	975	647	+ 51%
Reference transactions - one week sample	1,157	644	+ 80%
Circulation	139,544	132,928	+ 5%

Among the reasons for these increases are the filling of a professional staff vacancy, the promotion of circulation and processing section heads to supervisory positions thus releasing librarians for increased reference activity, and additional part time professional assistance from staff in other areas. It is also clear that the growth in enrollment in the Sloan School of Management's graduate programs along with a greatly enlarged faculty is contributing to increased use of this library. An additional professional staff position has been assigned to Dewey Library beginning July 1, 1990.

Another area of expansion is Dewey's special brand of library outreach -- the thesis consultation. Dewey librarians met with 56 students on an individual basis, usually for an hour. While this service is extremely labor intensive, it has proven to be quite beneficial for both students -- a better sense of the literature and information sources relevant to the thesis topic -- and for the librarians -- as a means of gathering data that is pertinent to improving the quality of the collections.

Two major CD-ROM services were fully implemented (CD-Corporate and Public Affairs Information Service) and a third (ABI/Inform) will be in place during the coming year.

SYSTEMS

Progress was made on the development of the new catalogue system during the year. Following a scan of existing systems that might be applicable to the needs of the MIT Libraries, several vendors were contacted by means of a Request for Information. Subsequent analysis of responses resulted in the identification of three systems for extended analysis. (A fourth system that became a viable contender during the evaluation process was later added.) Members of the Barton Operations Group took responsibility for setting up the test and designing the survey documents. Members of the MIT community were contacted through a variety of mechanisms -- advertisements in campus newspapers, the MIT cable, direct mail -- and asked to participate in the evaluation of the systems. Over 160 students, faculty, research staff, and library staff were involved in the process. Both specific comments and overall reactions to the several systems were incorporated into the final, internal review. The eventual decision was that Marcive was the system that the MIT Libraries will use for the new catalogue. The flexible system lends itself to a variety of storage media, including magnetic and CD-ROM. It is expected that contractual negotiations will begin in the fall of 1990.

Geac related efforts were focused on streamlining and fine tuning the system for maximum performance. Several indexes that have been maintained for the system and which consume a great deal of staff and machine time were discontinued, based on use data accumulated over several years. In addition, a new disk drive was installed providing greatly increased storage capacity. The Systems staff created software required to handle the records emanating from the OCLC retrospective conversion project. By year end over 20,000 records had been loaded without incident. Several items of equipment including a number of terminals were acquired from Boston College providing spare parts and lower maintenance costs. The staff tested dial access for the read-only components of the system (public access catalogue and news) and Geac electronic mail, with the goal of increasing response time and capacity of the Geac 8000. The Systems staff and Geac have begun working on a cooperative effort to develop software for extracting records for the new catalogue.

Support for microcomputing in the Libraries has been enhanced by the establishment of a position in Systems specifically devoted to this area. A new Microcomputer Resource Group with representation from throughout the system was formed to provide a forum for information sharing and communication. It complements the Microcomputer Policy Group established previously.

There were a number of significant developments in the general area of networking. At a local level, a small local area network was installed in the systems office to provide an opportunity for testing and experimentation. Ultimately, this type of system will be expanded to accommodate the needs of the new online catalogue configuration and linkages with the campus network. The Libraries also continued to build connectivity to Project Athena and the campus network. Efforts are underway to create a "library front-end" on Athena that will provide access to an array of services including Barton as well as catalogues of other libraries available through Internet. Scripts are also being prepared for access from machines on the MITnet, especially MITVMA. Network access is a collaborative effort with Information Systems and Project Athena and, in this regard, a new forum for the discussion of issues of common interest was formed during the year. The Athena/Information Systems/Libraries Discussion Group involves the senior administration of the three areas including the Vice President for Information Systems, the Executive Director of Project Athena, and the Director of Libraries. Among the topics covered were the Coalition for Networked Information, academic computing at MIT including the report of the Committee on Academic Computing for the 1990's and Beyond, and electronic information on the campus. The Libraries participated extensively in the presentation of a proposal to the Defense Advanced Research Projects Agency (DARPA) developed jointly by a number of universities (Carnegie-Mellon, MIT, Stanford, University of California at Berkeley, University of Illinois) to create an online database of full text computer science and artificial intelligence technical reports.

PUBLIC SERVICES

In addition to developments in Rotch and Dewey Libraries cited above, there were a number of changes and activities of note elsewhere in the divisional and branch libraries, in the Institute Archives, and in the Microreproduction Laboratory.

Online Services

The new EPIC information service from OCLC was installed on a pilot basis in the Humanities Library, in the Interlibrary Loan Office, and in the Computerized Literature Search Service. This system provides subject access to the OCLC database as well as some new search algorithms. Further distribution of access within the Libraries will be determined on the basis of use and cost studies currently being conducted. The Schering-Plough Library began providing MEDLINE searching for Whitaker College and the Medical Department. There has been substantial growth in the use of this library as evidenced by both circulation of materials and reference and information requests. There

was continued heavy use of the Library-funded literature searching service for MIT undergraduates. A new Chemical Information Advisory Service was implemented by the Chemistry Librarian. One component is an electronic bulletin board enabling the Librarian and his clients to communicate electronically. Extension of this system to provide access to external databases is being investigated. The Libraries also mounted an experimental electronic bulletin board on the MITnet as part of "Techinfo", a campus-wide current information service. Another experiment resulted in the production of a prototype Hypercard "tour" of the Libraries. The number of large scale searches continued to grow in the Computerized Literature Search Service. Included were bibliometric searches for Sloan School faculty and for patent cases; megasearches in which large amounts of bibliographic data is downloaded for transfer to local systems; and iterative citation analyses in which the results yield data on second generation citations (i.e. "who cited the citer?"). In support of the Libraries' continuing interest in the changing patterns of online database searching in a research environment, a Council on Library Resources Cooperative Faculty-Librarian Research Grant was awarded to Susan Bjorner, Senior Information Specialist in CLSS and Professors Michael Rappa of MIT's School of Management and Raghu Garud of New York University. The project will gather and analyze bibliographic references to cochlear implants as a tool in understanding technological development.

Outreach

The Libraries continued to expand its service to the large introductory subject given by the Department of Brain and Cognitive Sciences. The integration of library instruction and use into the course curriculum will be further enhanced by the assignment of librarian liaisons to each recitation section. The Libraries participated in several orientation/instructional sessions: for new international students; for Freshman Advisors; for MITES (Minority Introduction to Engineering and Science) students; and for Institute administrative staff. The Libraries have been invited to participate in the orientation for incoming MIT graduate students beginning in the fall of 1990. A program entitled "Library Days" was presented to students from the Shelburne Center School (a dropout prevention program in Roxbury), the Algebra Project (a program using a new curriculum to teach algebra to middle school students), Upward Bound, and Cambridge Rindge and Latin High School. The program, developed by Mark Scott, Assistant Engineering Librarian, enabled the students to explore the MIT Libraries and learn about the organization of information and the uses of information technology.

Institute Archives

Storage and automation were two areas of major concern to the Archives during the past year. A decision was made to use the RILIN system to provide bibliographic access to archival and manuscript collections. Implementation will begin in January 1991 and will fulfill three important goals: (1) to improve control and management of these collections; (2) to integrate information about holdings into the MIT Libraries' online catalogue; (3) to contribute information to the national bibliographic network. A significant amount of material was transferred from the RetroSpective Collection building to the Harvard Depository prompting a thorough study by the staff of the ramifications of off-site storage on activities like accessioning, processing, reference, and document delivery.

Use of the collections both from within MIT and outside continues to grow. Among the more heavily used were the Recombinant DNA History Collection and the Ellen Swallow Richards papers. Other researcher topics include the Brussels' World Fair, secondary school student programs at MIT, the Bemis Foundation, women in engineering education, scientific communication during the Cold War, and a biography of meteorologist Jule Charney. Publications and papers issued during 1989-90 that cited material in the Institute

Archives and Special Collections covered a wide range of subjects including New England textile mills, solar energy, women architects, radar in World War II, government support for science, the core memory, and early twentieth century engineering education.

Microreproduction Laboratory

The successful utilization of telefacsimile in the Microreproduction Laboratory provided the impetus for the acquisition of additional machines so that there are presently machines in each of the major libraries and in the RetroSpective Collection. The capacity now exists for the transmittal of requests and articles between RSC and the public service units thus reducing delivery time and also providing for better protection of older, fragile materials. The purchase of a photocopy machine especially suited for copying from fragile volumes has been installed in the RetroSpective Collection in support of this effort. Facsimile orders from outside have increased to an average of 25 per week although the number of items sent by this means remains low because of image quality and telecommunications costs.

TECHNICAL SERVICES

The long-awaited retrospective conversion project was inaugurated by the signing of a contract with OCLC in March, 1990. The plan is to convert approximately 175,000 monographic records over a period of 18 months. The project was well underway by the end of the academic year and converted records already appear in Barton. Responsibility for retrospective conversion was transferred from the Catalogue Department to the Bibliographic Database Services Department. Among other developments in bibliographic control were the assignment of contributed records cataloguing to the Copy-Based Cataloguing Section; completion of retrospective conversion of all reference collections; increased numbers of records contributed to the national CONSER (serials) and NACO (name authority) programs; and the establishment of procedures for handling large, multi-volume sets on Barton.

In the area of preservation and collection management, the ABLE automated system was installed and applications testing was begun. Based on a recommendation of the Theses Task Force, the Libraries began to provide hard binding for all MIT theses resulting in more permanent protection for these important and heavily-used items. There was a major transfer of materials from the RetroSpective Collection to Harvard Depository including a number of MIT dissertations and theses.

COLLECTIONS

The MIT Libraries received a grant from the National Endowment for the Humanities to support the preservation microfilming of approximately 1,350 volumes of 39 journal titles important to scholarship in the history of technology. Published between the 1820's and the 1930's, these journals are the basic historical record of the development of two major areas, electricity and transportation, and trace the growth of these technologies that have had a fundamental role in the shaping of society over the past century and a half. One additional title, Dingler's Polytechnisches Journal, covering the period 1820-1930 will also be filmed. This periodical is considered the single most important European publication in the history of technology for the period covered. Bibliographic records for all titles filmed will be available on the national networks and the film itself will be available on interlibrary loan.

A number of subject areas were identified for additional collections funding on a continuing basis. With inflation in serial prices having slowed down momentarily (a dramatic increase has been projected for the coming year) funds were available to add to book budgets where there had been a steady deterioration of purchasing power. The following is a list of libraries and subjects that received special attention:

Barker: artificial intelligence, applied computer science, computer architecture.

Dewey: management, arms control, international security.

Humanities: linguistics, interdisciplinary studies, women's studies, minority literatures, compact discs and videotapes for instructional programs in music, theater arts, psychology, philosophy.

Rotch: visual arts, environmental policy, architectural design.

Science: materials processing, polymers, superconductivity, biotechnology, nuclear reactor design, systems engineering.

In addition, several subject areas and material types were allocated additional funds on a one-time basis, essentially as a "catch-up" mechanism. Dewey Library received support for economic development monographs, conference proceedings in the management of technology, and back issues of economic newspapers on microfilm. The focus in Humanities was on scientific literacy, videotapes to support theater arts, literature, and back runs of journals covering short fiction. Barker funds were used for applied computer architecture and materials processing. The Science Library's allocation went to purchase books on polymers, biotechnology, superconductivity, neuroscience, toxicology, earth sciences at the undergraduate level, science for the non-scientist, materials science, and also for a CD-ROM product supporting access to spectral data.

Gifts

There were a number of major gifts of books and journals received during the year including the personal libraries of two deceased faculty members, Martin J. Buerger (crystallography) and Harold R. Isaacs (communications, political science, sociology). Other large gifts were received from John M. Deutch, Walter A. Rosenblith, David Saxon, and Harry L. Tuller. The offices of the Sloan Management Review and Technology Review continued to provide the Libraries with copies of review books. Several new collections were received in the Institute Archives documenting the teaching of electrical engineering at MIT. These included the student notes of Truman Gray from the 1920's, and the course notes of Richard Adler, professor from the 1950's until his death in 1990. Other collections received were the papers of the late Egon Orowan (physics and materials science) and David Middleton (communication technology). Several large collections were received from MIT departments and laboratories including the Energy Laboratory, the Laboratory for Nuclear Science, the Research Laboratory for Electronics, the Industrial Liaison Program, the Technology Licensing Office, and the Office of Minority Education.

SPACE

The Rotch Library addition took center stage for the entire year as it occupied the attention of the library staff and administration. There were, however, several other encouraging developments in this arena. At the end of June, the Libraries were notified that approval had been received for the repair and renovation of the RetroSpective Collection building. There are two aspects to this project. The first is the cladding of the building with fiberglass siding that will essentially seal the exterior except for a single row of windows at the office/reading room level. The second part of the project is the installation of air conditioning and humidity controls throughout the building. This long awaited decision will greatly enhance the quality of this space that serves as the near-campus storage facility for approximately 25 percent of the collections, including archives and records management materials.

Under the leadership of the Associate Director for Technical Services and Collection Management, a committee of staff from the departments that are located in room 14E-210 (Acquisitions, Bibliographic Database Services, and Catalogue) have been working on a

plan for the reorganization and redeployment of staff, equipment, offices, and library materials that will significantly improve the utilization of space in this area that has traditionally been the most overcrowded of all of the Libraries' facilities.

ORGANIZATION

The Document Delivery Study Group completed its work during the year and made a number of recommendations: (1) to establish a central retrieval unit; (2) to provide telefacsimile capability in the divisional libraries and RSC; (3) not to implement delivery to offices and laboratories; (4) to encourage the use of full text retrieval; (5) to establish speed of access as a guideline for interlibrary borrowing; (6) to consider making MIT library publications available online. With the exception of the first item which awaits implementation, the remaining recommendations were adopted and acted upon. Funding was received from the Institute for FY91 for full text document delivery. The Libraries will also be experimenting with full text access to newspaper articles. As reported above, telefacsimile machines have been installed in all major libraries.

A new study group was formed during the year to look at the current and future role of the Microreproduction Laboratory within the Libraries, at the Institute, and in the academic world in general. The report of the MRL Study Group is expected in August of 1990.

The Libraries became actively involved in the MIT Communications Forum. This is a confederation of MIT departments, centers, and laboratories interested in the political, social, and technical aspects of communication. The Forum sponsors a series of seminars each semester. The Libraries took responsibility for organizing two of these, one on individual privacy and the other on institutional privacy. In the fall of 1990, the Libraries will sponsor a seminar on access to government information.

The MIT Museum and Historical Collections became part of the Libraries in 1977. With the appointment of an Associate Provost for the Arts at MIT, administrative responsibility for that department was assigned to this new office beginning on August 1, 1990. The "Statistical Abstract" appended to this report reflects the reduction in collections and staff resulting from the change.

STAFF

David S. Ferriero, a long term member of the staff of the Libraries and most recently Humanities Librarian and Coordinator of Special Projects for Public Services, was promoted to the position of Associate Director for Public Services, succeeding Shirley K. Baker.

Three staff members with extensive records of service, retired from the staff at the end of the academic year. Peter R. Scott served as Head of the Microreproduction Laboratory since its founding and was a seminal figure in the field. He along with Ligija Neibergs, music cataloguer, and Armando Tontodonato, supervisor of binding, will be missed by all of the staff who had the privilege of knowing them. Their contributions to the advancement of the Libraries are greatly appreciated.

AFFIRMATIVE ACTION

During FY 1990, the Libraries completed eight national searches. Two minority librarians were appointed to the library staff as a result of these searches, bringing the total number of minorities on the professional staff to five, or 5.7 percent. This is still considerably under the percentage of minority librarians in research libraries nationally, but last year was one in which the MIT Libraries did make significant progress in meeting its affirmative action goals.

SPECIAL THANKS

This is the final report that the Libraries will submit to the administration headed by President Paul E. Gray and Provost John M. Deutch. The Director and staff wish to recognize the tremendous support that these two have provided during their terms in office. Provost Deutch will long be remembered for his creative leadership in the Rotch Library building program. He has also been steadfast in his support for the Libraries' acquisitions program. President Gray was a prime mover in the funding of the Libraries' online system and in the acquisition of a building for library storage. The Libraries have benefitted greatly from the guidance and support that President Gray and Provost Deutch provided and they will be missed.

JAY K. LUCKER

Lincoln Laboratory

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 1989 the operating budget was \$428 million, supporting the efforts of 865 professional staff, 83% of whom hold advanced degrees.

The following administrative change occurred at the Laboratory Steering Committee level during the year: Dr. David H. Staelin became Assistant Director.

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.

Terminal Air Traffic Control Automation

An effort has begun at Lincoln Laboratory to develop software and displays to help air traffic controllers improve terminal airspace capacity. Terminal air traffic control is a team effort involving physically separated controllers managing arriving and departing aircraft that are subject to unpredictable influences.

Lincoln Laboratory is developing new procedures, new automation software, centralized planning techniques, and means to enhance strategic and tactical coordination among these team members. All of these techniques will rely on advanced controller-interface technology. A simulation facility has been developed at the Laboratory to evaluate candidate automation techniques. Promising techniques will undergo field evaluation in various terminal areas.

Airport Surface Traffic Automation (ASTA)

Lincoln Laboratory has begun work in the Airport Surface Traffic Automation (ASTA) program. The multi-year program involves the use of advanced electronics for airport surface surveillance, processing and communications to improve safety, increase airport capacity and reduce controller workload. Safety is enhanced by use of data from radar and beacon surface surveillance systems together with advanced safety algorithms to implement automatic detection of hazardous surface traffic situations and to provide backup to the controller. Capacity is increased through a set of automation aids which assist controllers in planning for surface traffic movements. Although not expected to be fully implemented until the late 1990s, early ASTA safety features will be in operation within three to four years at the 31 largest airports in the United States.

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 is conducting a program for the FAA to evaluate the applicability of Electronic Scan and Mode S secondary surveillance radars to parallel runway approach monitoring. This activity has included field studies at the Raleigh-Durham, NC, and Memphis, TN, Airports to characterize radar performance, aircraft flight paths, and the response of air traffic controllers to high resolution displays and automatic alerts. The potential benefits of precision radar monitoring will be estimated and recommendations regarding equipment deployments developed.

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 and turbulence detection algorithms will be utilized in the Terminal Doppler Weather Radar (TDWR) to be deployed at major airports starting in 1993. Additionally the Laboratory is investigating the use of Air Surveillance Radars 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 currently is in Orlando, FL. 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.

Unmanned Air Vehicle Radar

Lincoln Laboratory has built a compact radar configured for a small unmanned air vehicle (UAV). 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. This program recently achieved significant success during evaluation of Ft. Sill. 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. Based on the radar's measurements, the UAV 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.

Model Based Automatic Target Recognition

The Machine Intelligence Technology Group has been developing a flexible experimental target recognition system using an approach based on a hierarchy of target appearance models. This system has been applied to CO₂ laser radar range and intensity imagery. On a data set of 180 images (tanks, howitzers, and armored personnel carriers), recognition rates of 90-100% were achieved. This past year the system was adapted to process downlooking GaAs laser radar range and intensity images of large vehicles. On imagery collected in winter conditions, covering approximately 1.3 square kilometers, the system was able to detect and recognize all 22 vehicles with no false alarms. On summer imagery, which is more stressing due to the presence of overhanging foliage, 11 out of 15 vehicles were recognized over 0.8 square kilometers with only one false alarm. Current efforts are focused on extending these techniques to millimeter wave tactical target imaging.

Wafer-Scale Adaptive Nulling Processor

The Laboratory's restructurable wafer-scale integration technology is being applied to the problem of adaptive nulling. A special-purpose processor has been designed which will support sixty-four degrees of freedom, i.e., handle up to sixty-four jammers, simultaneously. The wafer-scale implementation will result in a package measuring roughly 10x10x3 cm, with an equivalent throughput of approximately two billion operations per second (2 GOPS), and dissipating twenty watts of power. The system architecture is a 'folded', linear systolic array, with each element communicating only with nearest neighbors. Each element in the array consists of three custom cells which perform CORDIC (COordinate Rotation DIGital Computation) operations. A succession of CORDIC operations ultimately yields the desired adaptive nulling weight vector. A testbed comprised of twelve CORDIC chips has been completed, and has demonstrated 50db of nulling for simulated data. A wafer-scale processor, currently in fabrication, will contain 96 CORDIC cells.

Optical Discrimination Technology Program

For several years, Lincoln Laboratory has been developing a demonstration system for long-range imaging of objects using a carbon-dioxide laser radar. During the past year, system integration at the Firepond research facility on Millstone Hill in Westford, MA, was completed. The system makes use of a high-power, wideband CO₂ laser transmitter coupled with a 1.2 meter diameter telescope and coherent Doppler signal processing in the receiver to form range-Doppler images of objects in space. The first of several planned targets launched by sounding rocket from NASA's Wallops Island Flight Facility in VA was successfully imaged by the Firepond system on March 29, 1990.

Adaptive Optics Technology

When laser beams and other optical signals propagate through the atmosphere, their wavefronts experience distortion. Typically this distortion is caused by atmospheric turbulence, and, with high-power lasers, thermal blooming. Turbulence is simply the naturally occurring temperature variation in the atmosphere, and thermal blooming is a spreading of a laser beam which results from a certain amount of the laser power being absorbed by the propagation medium.

The Laboratory's program in adaptive optics emphasizes compensation for the effects of atmospheric turbulence and thermal blooming on optical wavefronts. This is important for atmospheric optical communications, earth-based astronomy and high-power beam propagation from earth to space.

We are investigating compensation through an intensive theoretical and experimental effort. The experiments include a laboratory investigation of correctability of thermal blooming at very high (equivalent) power levels. In 1990 we observed the predicted "phase-conjugate instability" for the first time in a simulated atmospheric environment. We are now taking this investigation a step further by going to a horizontal-path situation in the real atmosphere. We continue to operate a field site in Maui to investigate compensation for atmospheric turbulence effects on an upward propagated beam (or equivalently on a downward propagated wavefront in the astronomical sense). Upgrades are being made to the Maui system to improve the image quality of the sources of interest.

Microchip Lasers

Miniature solid state lasers have been developed which have generated much interest because of their narrow linewidth, tunability and simplicity. These microchip lasers consist of a thin chip (< 1 mm) of an ionic solid state laser crystal such as Nd:YAG whose faces define the laser cavity. The crystal is efficiently pumped by a diode laser collinearly with the output beam. Microchip lasers operate in a single longitudinal mode because the axial mode spacing of the cavity is comparable to or larger than the gain bandwidth of the gain medium.

Nd:YAG microchip lasers have demonstrated linearly polarized, fundamental-transverse-mode operation at 1.064 μm and 1.32 μm , with output powers in excess of 50 mW. The linewidth has been measured to be less than 2 kHz, and they have been piezoelectrically tuned over a range of ± 300 MHz, with a tuning response of 0.6 MHz/V at drive frequencies up to 300 kHz. The potential exists for electrooptic tuning at far higher rates over a much larger range. In pulsed operation, output pulses of less than 100 ps full width at half-maximum have been obtained.

Microchip lasers are among the world's smallest and least expensive lasers. At the same time, they have extremely desirable operating characteristics, which are difficult to obtain using more conventional laser designs. The combination of high performance and low cost make microchip lasers attractive for a large range of applications, including fiber optic communications, optical storage and medicine. The technology of microchip lasers is currently being licensed to industry.

High-Speed Devices Using Resonant-Tunneling Diodes

Resonant-tunneling diodes based on carrier transport through semiconductor quantum wells have been developed for operation potentially at terahertz frequencies. The diode structure consists of a thin (2 to 20 nm) quantum well sandwiched between two even thinner (1 to 5 nm) barriers. The barriers are made from a semiconductor that has a larger bandgap than the well and outer contact regions, e.g., GaAs quantum well sandwiched between barrier layers of AlAs, with GaAs contact regions. Because of the discrete energy states for electrons in the quantum wells, the current associated with electron tunneling through the barriers peaks at certain values of applied voltage and drops to a minimum at others. The resulting regions of

negative differential resistance can be utilized in high-speed switching devices and high-frequency oscillators.

Submillimeter oscillators using double-barrier resonant-tunneling diodes mounted in single-mode waveguides have so far exhibited oscillations up to 700 GHz. Self-oscillating mixers at 100 GHz and resistive multipliers to 400 GHz have also been demonstrated. A switching time of 2 ps has been measured, the fastest response for a room-temperature electronic switch to date, and digital AND/OR gates have been built with this switch. Because of these encouraging results, the application of resonant-tunneling diodes to high-speed logic and analog signal processing circuits is under way.

Laser Satellite Communications

A laser transmitter has been successfully qualified for use on a space platform. The successful flight qualification of this 30 milliwatt semiconductor laser transmitter (and an accompanying laser diagnostic module) represents a major advancement in the development of space-borne optical communications.

The transmitter is a key subsystem of the Laser Intersatellite Transmission Experiment (LITE) program. This experiment in high-data-rate coherent optical communications is designed to deliver 220 Mbps over a 23,000 mile satellite-to-satellite link.

The transmitter, which survived space qualification testing, weighs 2.0 kg and contains four redundant 30 mW semiconductor diode lasers operating at a wavelength of 0.86 micron.

Other portions of the LITE package are being constructed and will each be subjected to rigorous flight qualification testing. These subsystems include highly accurate pointing and tracking mirrors, a 20-cm telescope, optical beam relay and processing components, and lightweight yet rigid mechanical structures.

EHF Satellite Communications

Lincoln Laboratory has built two FLTSAT EHF Packages (FEPs) for flight on FLTSAT satellites F-7 and F-8. F-7 was launched on an Atlas/Centaur booster in December 1986. The second FEP was integrated with its host satellite (FLTSAT-8) in December 1986 and was initially due to be launched in July 1987. A mishap on the launch pad at Cape Canaveral, FL, resulted in damage to the upper stage of the Atlas-Centaur booster for this mission. The rebuilt booster was successfully launched on 25 September 1989. Following a period of on-orbit checkout, FEP-8 began its operational service under Navy control on 13 February 1990.

The FEPs incorporate spread-spectrum and on-board signal-processing techniques in order to provide robust satellite communications at extremely high frequency (EHF) for small mobile terminals. The communications capabilities of a FEP are a subset of those of a full Milstar satellite payload. Having the FEPs on-orbit makes possible the early operational test and evaluation (OT&E) of the Milstar terminals being developed by the Navy, Air Force, and Army.

CCD Imager Technology

Charge-coupled device (CCD) imagers are under development at Lincoln Laboratory for use in large-area, high-resolution, low-light level imaging for ground and space surveillance and for use in high frame rate, high-sensitivity cameras for wavefront measurements in adaptive optics experiments. Recent improvements in fabrication and circuit design have led to devices with noise levels of 1.7 electrons rms at 50 kHz clock rates, the lowest noise ever reported. In the past year we have developed techniques to improve the quantum efficiency of the imager and to extend its spectral range into the UV by chemically removing most of the device substrate and illuminating the imager from the back rather than through the gate structure on the front. The finished device is only about 10 micrometers thick, and for structural support is epoxied to a glass substrate with the circuit side of the imager face down. Devices built with this technology show good quantum efficiency in the visible (~ 60%) and near UV and the promise of extension into the vacuum UV. Using these devices, we have constructed high frame rate cameras that provide the sensitivity required for the wavefront measurement.

As an extension of the visible band imager work, Lincoln Laboratory is developing CCD arrays that operate in medium wave infrared (MWIR) bands. These sensors augment visible sensors by providing surveillance of space objects while in the shadow of the earth through detection of thermal emission from the spacecraft. These CCDs use Schottky barrier diodes of PtSi and/or IrSi as detectors imbedded in the CCD charge transfer registers. Large Arrays are being developed that provide improved quantum efficiencies in a continuous wave-band from 0.15 to 10.0 microns and will operate with high charge transfer efficiency and low noise in low sky backgrounds and at temperatures as low as 35 degrees Kelvin. An IRCCD array has been demonstrated that exhibits pixel-to-pixel fixed pattern noise levels less than 0.2%.

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 has initiated the development of a visible sensor package which will be flown on the Midcourse Space Experiment satellite to be launched in 1993.

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 comprises an array of 64 slave elements, each operating at 6 MOPs and containing 128K words. The combined throughput of SP2 is 384 MOPs and its total memory is 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 January 1991.

In order to realize the full economic and performance potential of the SP architecture, Lincoln Laboratory is in the process of contracting for the development of a monolithic SP slave element. This chip will combine 32-bit floating point operation with 4 Mbits of on-chip memory. A fully programmable processor using 4096 such devices would provide a throughput of 240 GFLOPs in a package of 2 cubic feet and consuming about 5 KW.

Optical Aircraft Measurements Program

The Optical Aircraft Measurements Program (OAMP), is an airborne infrared sensor used in gathering high-quality infrared data in support of research in ballistic missile defense. Developed by Lincoln Laboratory under the sponsorship of the U.S. Army Strategic Defense Command, the program included extensive modification of an RC-135 aircraft as the sensor platform. The aircraft was provided and modified by the Air Force Logistics Command.

The significant technology in the sensor development included a focal plane containing a large number of individual IR detectors with a radiometric sensitivity close to the physically realizable performance, very low line-of-sight jitter in an airborne environment, a cooling system for maintaining the IR telescope and focal plane at cryogenic temperatures, and a complex computer control and signal processing system for generating and processing large amounts of data in real time. A particularly challenging task was the structuring of the sensor to fit within the weight and space limitations of the aircraft.

OAMP was deployed to its operational base in the summer of 1989. Operator proficiency training was completed and full operations began in March 1990. Significant data on objects of interest has been gathered and data analysis has revealed new insights of importance to ballistic missile defense. Lincoln Laboratory continues to be responsible for the sensor performance and upgrades. The Laboratory also reduces and analyzes the data and distributes it to other users.

Radar Surveillance Technology Program (RST)

The RST Program is a Navy-sponsored activity to identify, develop, and demonstrate the surveillance radar concepts and technologies required to upgrade surface fleet defenses. The program activities supporting this objective include systems analyses in the radar configuration, ECCM, target parameter estimation, and false-alarm control areas. The hardware emphasis currently is placed on an ultra-low azimuth sidelobe planar array antenna with digital adaptive nulling in elevation, a solid-state transmitter with exceptional phase stability, and a digital adaptive beamforming processor. Subsystems are being assembled into a test-bed radar for target detection, jammer-suppression, and clutter-rejection experiments. A proof of concept

demonstration, using the test-bed radar and other Navy sensor elements, is being planned in 1992.

Large-Vocabulary Continuous Speech Recognition

A robust Hidden Markov Model continuous speech recognizer has been extended and improved to yield 98.3% correct word recognition in the 1000-word vocabulary DARPA Naval resource management task. Specific system improvements include modeling of cross-word-boundary effects on phonemes, and improved Gaussian mixture models for speech parameters. A new control and interface structure has been developed for integration of speech recognition and natural language processing in a spoken language understanding system. The system includes an efficient stack decoder search control for speech understanding, and a modular interface which will allow integration and test of a variety of speech recognition and natural language processors.

Neural Networks for Speech Recognition

In the speech recognition area, many different neural network classifiers including radial basis function (RBF), group method of data handling (GMDH), hypersphere, multi-layer perceptron, and high-order net classifiers have been implemented and compared to conventional classifiers on speech problems. The neural net classifiers sometimes provided lower error rates, but always provided tradeoffs in memory requirements, training and recognition time, ease of application, and ease of adaptivity. Experiments with generic search algorithms demonstrated a substantial reduction in both the number of input features and the amount of memory required for nearest-neighbor classifiers with no degradation in classification error rate. Initial experiments and theoretical analyses have demonstrated that neural network classifiers in a hybrid Hidden Markov Model (HMM) recognizer estimate Bayes a posteriori probabilities which can be integrated over time using the HMM. Experiments with a physiologically-based front end for speech recognition demonstrated slight performance improvements in noise.

Neural Networks for Object Recognition

In the object recognition area, a previously demonstrated 2D recognition system has been extended to recognize 3D objects from a sequence of 2D views of an object in continuous motion. The 3D system uses representations of different views derived by the 2D system to build a network representation of a 3D object in terms of a graph, where each node represents a 2D view and each connecting arc between nodes represents an allowable transition between views of that particular object. Object recognition is accomplished by accumulation of evidence over single and multiple views. In this approach, 3D objects that have some views which are indistinguishable can still be recognized from the sequence of transitions between views. This neural vision system currently running on a Lisp machine is being coded to run on the Lincoln MX-1 multiprocessor for evaluation on larger data sets.

Project Athena

INTRODUCTION

In May 1983 MIT initiated the Project Athena experiment in partnership with Digital Equipment Corporation (DEC) and International Business Machines Corporation (IBM). The two main goals of Athena were to design and implement a coherent distributed computing system of advanced workstations on the MIT campus, and to explore innovative uses of computers to improve the overall quality of the MIT education.

To accomplish the first aim, the computing model was designed around the emerging multitasking, interactive UNIX workstations with large monochrome graphics screens, powerful CPU capability, and Ethernet interface. Today, the Athena system consists of over 1100 networked DEC and IBM workstations distributed around the MIT campus.

The system is widely available to the MIT community. All undergraduate and graduate students, faculty and subject areas may use Athena. On a typical day in the spring of 1990, some 2500 different users access their personal files, various application software packages, and courseware from over 120 subjects. The workstations access 70 servers and 80 laser printers.

THE ATHENA COMPUTING SYSTEM

The Athena system is a *client server* model, with client workstations accessing or being supplied numerous services by servers on the network. The design goal was a network that could handle up to 10,000 users and workstations with a less than linear increase in support costs. Such a system would permit all members of the MIT community to have access to all computers located in clusters, classrooms, libraries, laboratories, offices, and student living groups.

Essential to the performance of the system is a high-speed, robust network. MIT's network consists of a fiber-optic spine with gateways to 40 Ethernet subnets. All workstations and servers are on the subnets. Athena is but one customer on the MITnet which serves 2500 machines including an IBM 3090 and Cray 2 mainframes. Worldwide access is available via the Internet.

The client-server model provides a practical approach for system growth. Centrally managed services are concentrated so that a relatively small staff can support the system. Yet the client workstations are widely distributed geographically and security of software on the public workstations is not required. Capabilities may be added relatively easily with a new server, typically a minicomputer.

Athena has selected and developed software that can operate in a coherent network containing products from multiple vendors. The Berkeley Standard Distribution (BSD) version of UNIX operating system was selected for its open architecture and rich capability. X Windows, developed at MIT jointly by Project Athena and the MIT Laboratory for Computer Science (LCS), provides a low-level standard multiwindow display protocol. The Motif user interface from Open Software Foundation (OSF) has been adopted for a common look and feel. The Athena authentication server, Kerberos, is rapidly becoming an industry standard.

Project Athena sought to establish a computing infrastructure that was ubiquitous on the MIT campus. Today, there is one workstation for about every 10 people with Athena accounts. The workstations are located in 15 public and 25 departmental clusters and are available to users 24 hours a day. They are also located in one classroom, two lecture rooms, five student housing facilities, 150 faculty offices, and Athena staff offices. This combination of numbers and locations, together with dial-up service, puts Athena within easy reach of most users.

In addition to the physical installation, students and faculty in all departments have access. In fact, students establish their Athena accounts (which are free of charge) themselves without administrative intervention. Currently 92 percent of undergraduates, 55 percent of graduate students, and 25 percent of the faculty have accounts. The architecture of the Athena system permits any user to use any workstation. And to the user, each workstation looks like his or her own personal device.

THE ATHENA EDUCATIONAL EXPERIMENT

The Athena Experiment included significant expenditure of resources for curriculum development. Priority was placed on innovative courseware to improve the quality of MIT's education over utilities such as text processing and programming. (Nevertheless, these have become a significant fraction of the total use of Athena.) During the first five years of Athena, 125 curriculum development projects were funded, involving perhaps 175 MIT faculty as well as numerous student programmers.

These projects were underway during constant changes in the operating system, and without the availability of well-designed application building tools. Central Athena support was primarily financial, with little support for design or application programming. Thus the environment for the courseware developers was far from supportive.

Despite these disadvantages, about a third of the projects led to courseware in use during the 1989-1990 academic year. Over 120 subjects give assignments that require access to Athena. Four projects have won national awards.

The educational projects encompassed a wide diversity of pedagogical approaches. Faculty from 21 of MIT's 23 departments participated, with the School of Engineering and School of Architecture and planning being the most active. Projects ranged from a single faculty member testing an idea with a relatively small expenditure to several projects in the million dollar range involving a team of faculty and multiple subjects.

SPECIAL ACCOMPLISHMENTS

During the 1989-1990 academic year, a number of special milestones were recorded. These include:

- All graduate students were given access to Athena
- The 1000th workstation was installed
- Project Athena was reviewed by the New England Association of Schools and Colleges as part of their accreditation visit
- The number of users in a single day exceeded the 3000 mark
- Approximately 4000 visitors from other universities, industry, and government agencies around the world visited Project Athena
- The Project Athena computing system was installed at Bond University in Australia, North Carolina State University, and Iowa State University.

EARLL M. MURMAN

Associate Provost for the Arts

INTRODUCTION

Following the recommendation of the Ad Hoc Committee to Review the Creative Arts at MIT, the position of Associate Provost for the Arts was established to oversee, coordinate, and facilitate arts activities at MIT. The Associate Provost for the Arts oversees the Office of the Arts, the List Visual Arts Center (formerly in the President's Office) and The MIT Museum (formerly in the Libraries). The Office of the Arts contains three programs: Arts Communications (formerly in the News Office), Council for the Arts (formerly in the President's Office), and Special Programs (including the proposed campus-wide Artists-in-Residence Program). In addition, the Associate Provost for the Arts coordinates academic and curricular programs in the arts through the newly established Creative Arts Council, whose members consist of arts leaders across campus (see below). The Creative Arts Council advises the Associate Provost for the Arts in individual programmatic areas, general curricular issues, facilities, fund-raising, and MIT's relation to outside cultural and educational institutions. Finally, the Associate Provost for the Arts facilitates arts activities on campus through communication and fund-raising.

Creative Arts Council

The Creative Arts Council (CAC) was established in the autumn to take its place beside the other faculty councils and to bridge the gaps between arts programs residing in different schools and departments within the Institute. Its members include the Dean of the School of Humanities and Social Sciences, the Dean of the School of Architecture and Planning, the Chairs of Architecture, Media Arts and Science, and Music and Theater Arts, the Directors of the List Visual Arts Center, The MIT Museum, Theater Arts, Visual Arts, and Dean's Representatives from the School of Engineering, the Sloan School of Management, and the School of Science. Some of this year's areas of discussion are listed below.

Undergraduate curriculum: The Associate Provost served as Chair of the Arts Subcommittee to the Humanities, Arts, and Social Science Distribution (HASS-D) Overview Committee. The role of the arts in this curriculum was discussed by the CAC, focussing on two issues. First, the arts component is the only one of five not required. Even though the arts courses are heavily enrolled, this discrepancy in requirements possibly sends a negative message to the students concerning the role of the arts in their education. Second, the arts courses are currently divided between active ("hands-on") and reflective (analytical) approaches. For example, there are courses in studio art and art history, music theory and music history, and playwriting and history of drama. Although the different approaches are good, the arts community is working to develop courses with a combined approach. The new HASS-D course in modern dance combining the history of dance, choreography, and performance is a model for other introductory courses.

Facilities: The continuing and increasing need for facilities for arts programs is of constant concern. The major renovation of the first and third floors of N51-52 for the new undergraduate Visual Arts Program, which should be completed for autumn 1990 classes, is an important step in acquiring appropriate space. In addition, the installation of new sprung floors in the T-Club Lounge and Walker 201, through the coordination and cooperation of the Office of the Arts, the Athletic Department, and Physical Plant will make a critical improvement in our facilities for dance. The coordinated use of space is especially important when space is limited. The arts community benefitted from the use of the Villers Experimental Media Facility ("The Cube") for dramatized performances presented by the MIT Theater Arts Program ("Leonardo: Anatomy of a Soul") and the List Visual Arts Center ("Black Dirt"). Also the Media Arts and Sciences Section made the Beckwith Photography Laboratory

available to the Visual Arts Program undergraduate courses in advance of the completion of the new undergraduate photography laboratory in N51-52.

One-percent for the arts: MIT was the first educational institution to establish a "one-percent for the arts" program, devoting one percent of the cost of new construction and major renovations to the acquisition of art. The Office of the Arts will be overseeing this program. In the past year, the office dealt with the controversy concerning the proposed sculpture by local artist Mags Harries for the Stratton Student Center. The artist was chosen by a committee made up of members from across MIT community, including students. Concerns were voiced, however, about procedure, as well as about siting and artistic medium. Meetings between the artist and the MIT community, as well as between the Associate Provost and the MIT community led to invigorating discussions of some of the central issues involved in public art. These will continue in the autumn, will influence the final decision about the installation of art in the Student Center, and will affect the procedures for future "one-percent" projects, including the Rotch Library and the new Graduate Dormitory.

Affirmative Action

The offices under the supervision of the Associate Provost for the Arts are actively supportive of affirmative action goals. Because women are strongly represented in the arts, our record appears very strong. We actively seek minority candidates for all positions, but unfortunately there are no minorities among current employees. The Office of the Arts employs seven people, six of whom are women. The List Visual Arts Center employs sixteen (eleven EFT), eleven of whom are women. The MIT Museum employs twelve, six of whom are women.

Fund-raising and the Campaign

The Arts at MIT were recognized as a separate entity in the revised Campaign priorities. The \$5 million goal includes funding for the proposed Artist-in-Residence Program, support for the permanent collections of the List Visual Arts Center and The MIT Museum (for acquisition, conservation, and storage), arts facilities, and professorships and fellowships in the arts. The Associate Provost for the Arts took part in many cultivational events, and it is hoped that these will increase giving to the arts at MIT. Because of the loss of state funding due to the reorganization and budget cuts to the Massachusetts Council for the Arts and the projected loss of federal funding following the reauthorization hearings for the National Endowment for the Arts and the National Endowment for the Humanities, fund-raising for the arts from other sources has become even more important. During the past year, the arts benefitted from a number of important gifts. Margaret McDermott created the Eugene McDermott Fund for the Arts, an endowment that will help to support the Artists-in-Residence Program and other arts activities. Ronald A. Kurtz '54 MG underwrote the entire cost of the new photography laboratory in N51-52 for the Visual Arts Program; the laboratory will be named after Berenice Abbott, whose photographs of natural phenomena, commissioned by MIT in 1958, have so successfully represented the nexus of art, science, and technology. Martin Zimmerman '59 EE has made funding available for the next five years for exhibits of architectural materials in The MIT Museum. Various donors have assisted with the funding needed to send the MIT Theater Program production of "Leonardo: Anatomy of a Soul" to Europe and to the Edinburgh Festival; this trip was also generously supported by the MIT Summer Session.

Personnel

Ellen T. Harris, formerly Professor of Music at The University of Chicago, joined the faculty of MIT as Professor of Music and Associate Provost for the Arts. Mark Palmgren, formerly Program Officer of the Council for the Arts, joined the Office of the Arts as Director of the Council for the Arts. China Altman, formerly Assistant Director (Arts) in the News Office, joined the Office of the

Arts as Director of Arts Communication. Sara Elizabeth Wilbur, formerly Visitor Services and Concert Coordinator with the Museum of Fine Arts, Boston, will join the Office of the Arts as Director of Special Programs.

Elizabeth Connors, formerly of Brain and Cognitive Sciences, is Administrative Assistant. Lynn Heinemann, formerly of the News Office, is Senior Staff Assistant. Susan Cohen, also a Gallery Attendant at the List Visual Arts Center, is Staff Assistant.

ELLEN T. HARRIS

Office of the Arts (Arts Communication, Council for the Arts)

ARTS COMMUNICATION

In this first year for the Office of the Arts (OA), "communication" described an approach and an aspiration for projects involving public relations and coordination.

Public Relations as it was shaped in the OA encompassed: 1) publication and distribution of the Arts Page, with the goal of raising awareness--internally and externally--about MIT's world of arts, its individual and collective aspects; 2) cultivation of media contacts in general and media support on specific projects involving MIT arts; 3) serving as an information resource for internal/external media and cultural/community groups; 4) public relations assistance to the Associate Provost for the Arts; and 5) central calendaring. Coordination involved consulting, information gathering, and fostering of collaborative projects within the 65-member ARTSNET and the arts community at large.

Major accomplishments in communication included the following.

--Ellen Harris was introduced in a Tech Talk leading article accompanied by a summary of changes and new developments. This was developed into an announcement sent to 250 media sources and used as a public relations handout during the year.

--A four-page State of the Arts insert--including photographs and essays from 12 MIT arts leaders and an introduction by Professor Harris--was published in Tech Talk and used in public relations and information projects throughout the year by the OA, MIT arts centers and by the Admissions Office.

--Graduate student Robert Newman became the first photographer in a project developed by the OA, sharing expenses with the Communications Office. A series on the 16 year-long students of the Advanced Music Performance program, and other coverage of students and faculty in the arts resulted in a rich collection of photos for the Arts Page, the MIT Catalog, various brochures and publications, Technology Review, and The Tech, among others.

--When controversy developed over a proposed Student Center sculpture by artist Mags Harries, OA communication worked with the Associate Provost, the List Visual Arts Center, and the staff of the Student Center to develop and promote a series of public investigations and discussions, including public relations work with campus media, and publishing coverage of efforts and developments.

--OA communication collaborated with faculty, staff, and students of the Theater Arts Program to help create a celebration and an award to honor Edward Darna's 25 years in theater arts. One component was the Edward Darna Arts Page which--in addition to its original purpose--was designed for fund-raising and development use.

--Five Month-At-A-Glance Arts Pages and 21 feature Arts Pages were published and distributed through Tech Talk, selected media contacts, a bulletin board network, and newsletter mailing to the Council for the Arts. Some ten other arts pieces were published in Tech Talk's general spaces. Special arts sections were included, for the first time, in the weekly IAP guide.

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

--Press release responsibility for events was disseminated to sponsoring programs and departments.

--Senior staff assistant Lynn Heinemann assumed responsibility for the 24-hour Arts Hotline updated every Monday. She collaborated in all communications areas and made a promising start toward developing a system for a central electronic arts calendar. She studied Filemaker and Pagemaker, expanding her abilities as assistant editor of the Arts Page. Staff Assistant Susan Cohen learned word processing and graphics programs on the Macintosh, and began developing various graphic arts skills in order to assist in layout and production of the Arts Page.

CHINA ALTMAN

COUNCIL FOR THE ARTS

The fruitful partnership now established between the Council for the Arts and the MIT Office of the Arts, headed by Associate Provost for the Arts, Professor Ellen T. Harris, represents the hallmark of Council activity this year. As a result of its new position within the Office of the Arts, the Council has rekindled its productive relationship with the MIT cultural community. The members of the Council have been reinvigorated with a clear vision of their ongoing contributions to the robust health of the arts at MIT.

Annual Meeting

The Seventeenth Annual Meeting of the Council for the Arts was held on October 19-20. The affair began with a "Tribute to Jerome B. Wiesner" upon his retirement as Council Chairman, a post he had held since 1979. Walter A. Rosenblith presided at the celebratory dinner, with fond anecdotes and warm remarks offered also by Howard Johnson, John Kunstadter '49, and Yulla Lipchitz. As an emblem of profound respect and friendship, the Council presented Dr. Wiesner with a gouache by the American sculptor, Jacques Lipchitz. This gala dinner was held at the Royal Sonesta Hotel in Cambridge, through a generous donation from Roger Sonnabend '46, a former Council member.

The 1989 Eugene McDermott Award was presented to Ida Ely Rubin, a founding member of the Council, honoring her as "a rare and captivating catalyst [who] has struck sparks at the intersection of art and technology." One highlight of the award ceremony was the attendance of Margaret McDermott who bestowed the award, named in honor of her late husband, to Ida Rubin, a long-time friend.

Catherine N. Stratton, Council Vice Chairman, presided over the business meeting conducted on the morning of October 20. Mark Palmgren, Program Director, presented the FY89 financial report. After a full discussion by the assembled members, a new Council for the Arts constitution was unanimously ratified. While reaffirming the Council's mission to foster the arts at MIT, this document describes a revamped Council structure necessitated by the reorganization of arts management at MIT. Structural reforms include the revised composition of the Council's Executive Committee and the establishment of six standing committees (*see Council Standing Committees below*).

President Paul E. Gray '54 formally welcomed the Council at this time. At the conclusion of his remarks, he appointed John W. Kunstadter '49 and Martin N. Rosen '62 as the new Chairman and Vice Chairman of the Council, upon the retirement of Jerome B. Wiesner and Catherine N. Stratton. Provost John M. Deutch '61 introduced Ellen T. Harris, Associate Provost for the Arts and Professor of Music, who addressed the Council on its prominent role within the new arts environment at MIT.

Council members and guests then proceeded to the MIT Faculty Club for luncheon. The 1989 Gyorgy Kepes Fellowship Prize was presented by Professor Ellen T. Harris to Richard Bolton, a photography instructor in the Department of Architecture, who was recognized for his work as a visual artist and critic.

The afternoon session consisted of a symposium, "Creative Arts at MIT," moderated by Professor Harris. Participants included Professors Alan Brody (Theater Arts), Ed Levine (Visual Arts), and Marcus Thompson (Music), and various student performers. A reception in the Catherine N. Stratton Lounge in the Julius A. Stratton Student Center concluded activities of the 17th Annual Meeting.

Council Standing Committees

As charged by the Council constitution ratified on October 20, six standing committees were established to undertake the Council's active work. The chairman of each committee is appointed by the Chairman and Vice Chairman of the Council in consultation with the Associate Provost for the Arts.

Following the Annual Meeting, individual Council members were selected to serve as committee chairs, and committee rosters assembled thereafter: Acquisitions (Ida Ely Rubin); Annual Meeting (Catherine N. Stratton); Development (Ronald A. Kurtz '54); Grants (Bradford M. Endicott '49); Long-Range Planning (Albert P. Hildebrandt '44 and Alan W. Katzenstein '42); Membership (Bernard G. Palitz '47).

With the exception of the Development Committee, each committee met on several occasions to organize activities and programs for next year. The Grants Committee continued to hold its quarterly sessions to review applications for arts funding (*see Grants Program below*).

Grants Program

The Grants Committee, chaired by Bradford Endicott '49, received and evaluated 47 applications for arts project funding from students, student groups, staff and faculty, requesting a total of \$81,580. Funding was recommended for 41 projects, with awards totalling \$63,633. Three Officer's Grant applications were reviewed by the Council Director and awarded \$550. A detailed report of Grants Program activity is available.

One noteworthy grant provided funding to arrange a spring semester series of student visits to the Boston Symphony Orchestra and the Museum of Fine Arts. Free tickets and transportation were available to up to 50 students each for three excursions to the *Monet in the 90s* exhibition, and two performances by the BSO. Substantial grants were awarded to the List Visual Arts Center to support publication of exhibition brochures accompanying a year-long program of contemporary photography; to Pilgrim Theater, artists-in-residence in the Theater Arts Program, to develop and produce a multi-media performance, *Leonardo: Anatomy of a Soul*, and to two Media Arts and Sciences graduate students, Joseph Stampleman and Uri Wilensky, to continue their popular series, *Poetry at the Media Lab*, with readings by local and national poets.

Endowed Prizes and Awards

The Laya and Jerome B. Wiesner Student Art Awards were presented to Jee-Hoon Yap '90 (Course VI) for achievement in music performance, and to Jonathan Richmond, graduate student (Course I), for his contributions to enriching student participation in the arts. The Louis Sudler Prize in the Arts was awarded to Jee-Lian Yap '90 (Course II) for excellence in music performance. Jee-Hoon and Jee-Lian Yap are twin sisters, and both are pianists. William M. Siebert, Ford Professor of Engineering, served as chairman of the Student Art Awards Selection Committee for the third year.

The Eugene McDermott Award was presented to Ida Ely Rubin, a founding member of the Council, at the 17th Annual Meeting on October 19 (*see Annual Meeting above*).

A McDermott Award Ad Hoc Selection Committee met several times during the spring semester to consider revised guidelines for this award.

The Gyorgy Kepes Fellowship Prize was presented to Richard Bolton, photography instructor in the Department of Architecture, at the 17th Annual Meeting on October 20 (*see Annual Meeting above*).

The Kepes Prize Selection Committee, chaired by Angus N. MacDonald '46, considered and approved revisions to the prize guidelines. Principal revisions included the addition of MIT undergraduates as eligible for prize nomination, and limiting consideration to only those candidates who work in the creative arts: architecture, visual and performing arts, and writing.

Museum Membership Programs

The Museum of Fine Arts University 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. Participation in this program was again made possible by special contributions from Bradford Endicott '49 and Bernard Palitz '47. Council members have funded MIT's enrollment in the program since 1980.

For the third year, MIT students were offered a discount admission fee to all exhibitions at the Institute of Contemporary Art (ICA) in Boston. MIT's institutional membership with the ICA has been provided through the generosity of Dr. Ellen Poss, an ICA trustee.

William L. Abramowitz Memorial Concert

The William L. Abramowitz Memorial Concert endowment provides funds to present a major performing arts event each year at MIT. Professor Alan Brody, Music and Theater Arts Section, agreed to organize and produce this year's event. On April 5, actor Avery Brooks, best-known for his role as "Hawk" on the television program *Spenser for Hire*, presented excerpts from his one-man show on Paul Robeson. The performance was enthusiastically received by a capacity audience in Kresge Auditorium.

Marvin A. Asnes Performing Arts Series

The first Marvin A. Asnes Performing Arts Series concert was presented on October 6 in Kresge Auditorium. Acclaimed jazz pianist and composer Michel Camilo performed with his trio to the delight of a full-house audience. The concert, sponsored by the Music and Theater Arts Section, was made possible through the generosity of the Marvin A. Asnes '49 Performing Arts Fund, established by Council member Norma K. Asnes, in memory of her husband.

Development Activities

With the establishment of the Office of the Arts, MIT now provides support for most of the Council's operating expenses. Thus, a substantially higher percentage of total Council revenues may be applied directly to programs and activities such as those outlined above.

Thirty-eight Council members offered contributions averaging \$3,490 each, and 26 non-member donors contributed an average of \$1,303 each. In addition to these unrestricted contributions to Council programs, a restricted sum of \$267,606 was donated by Council members to specific MIT art programs or activities.

Membership

At the conclusion of the year, Council membership stands at 66. Cynthia Tobias '72 resigned from the Council in September. Seventeen of the 25 members whose terms expired this year were invited to renew their participation.

With especial sadness, the Council regrets the death of Harold E. "Doc" Edgerton '27G, Institute Professor Emeritus, on January 4. Beloved by generations of the MIT community and friends of the Institute, "Doc" was one of the original members of the Council, and served for 17 years as an inspiring advocate of the arts. He was honored as the 1985 recipient of the Eugene McDermott Award.

Upon his retirement as Council Chairman in October (*see Annual Meeting above*), Jerome B. Wiesner was appointed as a Life Member of the Council, the first individual so designated, to acknowledge his leadership in the arts at MIT.

The Membership Committee, chaired by Bernard Palitz '47, met several times to review membership criteria and consider prospective members. Nine 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.

Personnel

Mark Palmgren was promoted to Director of the Council for the Arts in April.

MARK PALMGREN

List Visual Arts Center

LIST VISUAL ARTS CENTER

With the administrative restructuring attendant upon the appointment of Doctor Ellen Harris as Associate Provost for the Arts and the establishment of the Office of the Arts, the Committee on the Visual Arts, previously the advisory group to the List Visual Arts Center staff, was disbanded. Members were warmly thanked for their energetic interest and support of the arts of MIT.

Katy Kline, previously Curator, who also had been serving as Acting Director since July, 1986, was appointed Director; Dana Friis-Hansen was promoted to Curator.

EXHIBITION PROGRAM

Ten exhibitions in the three galleries continued to embody the List Center's commitment to presenting advanced contemporary art in all media.

Still Performances: The Gerlovins, Bakalar Gallery, September 5 - October 8, 1989. Large-scale color photographic portraits by two Soviet emigré conceptual artists who exploit the collision of image and language. Forty page catalogue published; organized jointly by the List Center with the Anderson Gallery, Virginia Commonwealth University.

Remo Campopiano: In Residence, Reference Gallery, September 5 - November 19, 1989. This Minneapolis-based artist combined concepts of myth and thought with natural ecosystems in his full gallery installation based on the four axes of the Native American medicine wheel. Supported by the New Works Program of the Massachusetts Council on the Arts and Humanities.

Richard Ross: Museology Triptychs, Bakalar Gallery, October 13 - November 19, 1989. The second in a series of Bakalar Gallery exhibitions celebrating the hundred and fifty-first anniversary of photography. This Santa Barbara-based photographer used a child's plastic camera to seize odd details of old master paintings strangely lit, scaled and juxtaposed. Brochure published.

Trouble in Paradise, Hayden Gallery, October 6 - November 19, 1989. Fourteen New England artists or artist-teams grappling with current political and social issues from censorship to homelessness to substance abuse. Forty-four page catalogue published. Exhibition will be reconstituted at the Art Gallery, University of Maryland, in September, 1990.

Against Nature: Japanese Art in the Eighties, Hayden, Reference and Bakalar Galleries, December 9, 1989 - February 18, 1990. Organized jointly by the List Art Center, the Grey Art Gallery at New York University and the Japan Foundation, Tokyo and presented in Massachusetts jointly with Bank of Boston Gallery, the exhibition consisted of painting, sculpture, photography and mixed media installation by ten young Japanese artists who contest the traditional nature-based Japanese aesthetic. MIT was the fourth on a seven stop national tour of major museums. Ninety-two page catalogue published. Supported by the Art Exchange Program of the Massachusetts Council on the Arts and Humanities and the National Endowment for the Arts as well as the Japan Foundation, the AT&T Foundation, the Japan U.S. Friendship Commission, the Asian Cultural Council and Bank of Boston.

Paper Architecture: New Projects from the Soviet Union, Hayden Gallery, March 14 - April 23, 1990. Shown for the first time in the United States, the exhibition of 80 drawings of visionary or theoretical projects executed between 1979 and 1989 following a period of architectural repression, was organized by the German Architecture Museum, Frankfurt and the Soviet Architecture League. The exhibition will travel to three other American museums under the auspices of the List Visual Arts Center. Supported in part by Lufthansa German Airlines.

Rebecca Purdum: Paintings, Reference Gallery, March 14 - April 22, 1990. First museum exhibition of the large canvases of an acclaimed young New Yorker who creates mysterious abstract works layered with rich mists of color by painting with the tips of her (gloved) fingers. Thirty-six page catalogue published.

Jno Cook: Radically Recycled Cameras, Bakalar Gallery, March 14 - April 22, 1990. This Chicago-based photographer, filmmaker and tinkerer exhibited quirky cameras made from reclaimed optical and mechanical junk and household castoffs, together with photographs they produced. Eight page brochure published. Supported in part by Arts Midwest.

Matt Mullican: The MIT Project, Hayden Gallery, May 12 - July 1, 1990. For fifteen years Mullican has developed a system of symbols and signs to describe the world and personal and social relationships within it. In the MIT project he deployed his found and fabricated objects for the first time in a three dimensional, quasi-architectural rendition of his signature 5-zone city plan. A sixty page catalogue published. Supported in part by the Massachusetts Council on the Arts and Humanities and the National Endowment for the Arts.

Bill Traylor: Drawings, Reference Gallery, May 12 - July 1, 1990. Beginning in 1936 at age 85, and working for the next three years, freed slave and self-taught artist Bill Traylor created a colorful, whimsical world of humans and animals remarkable for its directness and invention. Already presented across the U.S. and Canada, this popular traveling exhibition presented almost eighty works in pencil, paint, and crayon on paper, cardboard, and scrap advertisements.

Nancy Burson: The Age Machine and Composite Portraits, Bakalar Gallery, May 12 - July 1, 1990. This final exhibition in the Bakalar Gallery photography series contained the New York artist's startling computer-generated composite portraits which she began developing at MIT in 1975. *The Age Machine*, an interactive video photo booth, provided visitors with their computer screen image as it would age over 20 years. The sequence of four Bakalar exhibitions demonstrating unusual applications of photography received partial support from the Council on the Arts at MIT.

Special Projects: The List Visual Arts Center, with the Arts Company, co-commissioned a new multi-media non-narrative theater work by Robert Whitman, produced in the Villers Experimental Media Facility ("The Cube"), April 5-7 and April 12-14, 1990, before touring to The Kitchen in New York, May 10-13 and May 16-19, Painted Bride Art Center, Philadelphia, June 22-24 and June 29-July 1, and Walker Art Center, Minneapolis, October 24-27, 1990.

Outside Funding toward exhibitions and projects in FY 90 totalled \$261,962, an amount unlikely to be equalled in the future given the severe cutbacks at the Massachusetts Council on the Arts and Humanities and restrictions placed upon the National Endowment for the Arts.

EDUCATIONAL PROGRAMS AND EVENTS

Gallery talks by the artists and curators were given for every exhibition, and didactic wall texts were written to provide gallery visitors with an immediate explanatory introduction. Among special lecturers were James Fallows, editor of the Atlantic Monthly, who discussed aspects of popular culture in Japan in conjunction with *Against Nature* and Arthur Danto, art critic of the Nation, who elaborated a new theory of signs and symbols on the occasion of the Matt Mullican exhibition. Professor Steven Benton discussed the future of photography in conjunction with the Burson exhibition. Special tours were given by the Director and Curator to groups such as the International Council of the Museum of Modern Art; the Museum Council of the Boston Museum of Fine Arts; the Docents of the Fogg Art Museum and the MIT Campus Visit program.

MISCELLANEOUS HIGHLIGHTS

Katy Kline and Dana Friis-Hansen made research trips to San Diego and, with a Massachusetts Council Planning grant, to Europe (Basel Art Fair, Venice Biennale, Cologne and Belgium) visiting artists, studios, galleries and museums.

The List Visual Arts Center received an Award of Merit "in recognition of the highest standards of excellence" in the Museum Publications Competition of the American Association of Museums.

PERMANENT COLLECTION

An oil painting (*Figure 7*, 1959) by Jasper Johns and a Picasso etching, missing from the Permanent Collection since 1976, were recovered.

ACQUISITIONS

The following works were acquired through either gift or purchase during the 1989-1990 academic year:

Permanent Collection

Joan Fontcuberta and Pere Formiguera, *Micostrium Vulgaris* from Dr. Ameisenhaufen's Fauna, 1982, mixed media.

A. L. Drezner, *T.V. Table Triptych*, 1990, beeswax and oil on plexiglas, hardware, wood and latex. Gift of the Artist.

Per Kirkeby, *Untitled*, 1988, monotype. Gift of Vera G. List.

Student Loan Art Collections

Betye Saar, *Mumbo Jumbo*, 1987, color lithograph. Purchased with funds from the Student Center Preview Program.

Betye Saar, *As the World Turns*, 1986-87, color etching. Purchased with funds from the Student Center Preview Program.

Matt Mullican, *Bath Rubbing*, 1988, oilstick on paper. Purchased with funds from the Student Center Preview Program.

Buckminster Fuller, *Laminear Geodesic Dome*, 1981, companion set of 2 screen prints. Purchased with funds from the Student Center Preview Program.

Doug Anderson, *Met a Stranger on a Train #2*, 1986, watercolor woodcut. Purchased with funds from the Student Center Preview Program.

Karl Baden, *Untitled (Harold Edgerton/J.H. Lartigue)*, 1988, collage into photograph. Purchased with funds from the Student Center Preview Program.

Yvonne Jacquette, *Times Square*, 1987, woodcut. Purchased with funds from the Student Center Preview Program.

William T. Wiley, *Muddy Waters*, 1983, woodcut. Purchased with funds from the Student Center Preview Program.

William Wegman, *Ray Cat*, 1987, color lithograph. Purchased with funds from the Student Center Preview Program.

Nancy Spero, *Goddess*, 1987, color lithograph with lettpress cuts and hand coloring. Purchased with funds from the Student Center Preview Program.

Robert Moskowitz, *Moon Dog*, 1988, color woodblock print. Purchased with funds from the Student Center Preview Program.

Ellen Banks, *Chopin Mazurka in the Key of B*, 1988, acrylic and handmade paper. Purchased with funds from the Student Center Preview Program.

Todd Siler, *Metaphorms (Brainways in the Garden...)*, and *Metaphorms (Inside the Hidden Territory...)*, 1988, lithographs. Purchased with funds from the Student Center Preview Program.

Alexander Kosolopov, *Lenin Coca-Cola*, 1982, silkscreen. Purchased with funds from the Student Center Preview Program.

EXTENDED LOANS TO THE COLLECTION

M. C. Escher, *Day and Night*, 1983, 2-color woodcut. Lent by Martin N. Rosen.

(See also previous reports.)

LOANS FROM THE PERMANENT COLLECTION

Victor Burgin, *Danaïdes/Dames*, 1986, to the Museum of Fine Arts, Boston, for the exhibition Reproduction, March - July, 1989.

Various artists, 14 photographs and 2 prints, to the MIT Museum, for the exhibition Image and Imagination: 150 Years of Photography, July 1989 - March 1990. This exhibition was co-organized by the MIT Museum and Polaroid.

Berenice Abbott, 6 black-and-white photographs, to the Photographic Resource Center, Boston, for the exhibition Locomotion, December, 1989 - February, 1990 and subsequent tour to the Houston Center for Photography.

Maria Luisa Pacheco, *Petrous*, 1965, to the Bronx Museum of the Arts, New York, for the exhibition The Latin American Presence in the United States 1920-1970, September 1988 - January 1989 and subsequent tour to the El Paso Museum of Art, Texas, the San Diego Museum of Art, California, and the Center for the Arts, Vero Beach, California.

John Newman, *Untitled*, 1988, to David Nolan Gallery, New York, for the exhibition John Newman: Drawings, April - June, 1990.

Rollin McNeil Crampton, *Untitled*, to The Katonah Gallery, Katonah, NY, for the exhibition Watercolors of the Abstract Expressionist Era, March - June, 1990.

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.

CONSERVATION OF THE PERMANENT COLLECTION

Restorative work was performed on the surface of Alexander Calder's *The Big Sail* (La Grande Voile).

A damaged flange on Calder's Intermediate Model for *The Big Sail* was restored by Dædalus, Inc. of Cambridge.

Lowell Nesbitt's painting *Red and Yellow Tulip* was treated by the Center for Conservation and Technical Studies, Harvard University.

44 works on paper were framed or reframed by Old Cambridge Company, Charlestown, and by PSG Framers, Boston.

List Visual Arts Center Staff

MIT Museum

In FY90, the MIT Museum garnered international attention in both the art and science communities. Increasingly, the Museum is being recognized for its exhibits and programs which attempt to "discover where art and science meet." From France Magazine to PC Computing, the MIT Museum is reaching wider audiences as a result of a compelling roster of exhibits and programs, a vigorous public relations campaign, and a colorful new brochure which is distributed at most major hotels, conferences, and visitor centers in the area.

EXHIBITIONS AND PROGRAMS

The Museum's exhibition schedule continued at its usual vigorous pace—major exhibitions requiring significant research and interpretation interspersed with smaller, but nonetheless ambitious shows. Our exhibitions, organized and designed by Joan Loria, Assistant Director for Exhibitions, continue to offer a diverse menu, reflective of the multiplicity that is MIT and our broader constituency. Visitation continued on an upward curve.

Stopping Time 6 April - 15 September

Opening on Doc Edgerton's eighty-sixth birthday, this exhibition highlighted his life, work, and whimsy. A legend in his own lifetime, Doc's photography bears witness to the possibility of research being beautiful as well as useful. Edgerton never intended his photographic studies of motion to be art, but they were rapidly recognized as such. His inventions have revolutionized the way we see the world.

Lahore: The City Within 16 September - 17 December

Photographs and paintings by graphic designer Samina Quraeshi juxtaposed with Mughal watercolors from the Museum of Fine Arts Boston, carved wooden doors, windows, screens, and a bazaar festooned with exotic fabrics, rugs, and kites, created a Kiplingesque view of Lahore, the cultural capital of Pakistan. Associated programs included: "The Ancient Architecture of Lahore and the Future," lecture by Masood A. Khan; "The Magic of Classical Music, Dance and Urdu Poetry," lecture/performance by Dr. Brian Silver; and "Dance and Music at the Mughal Court," lecture/film by Susan Weiner. A four page full-color brochure was funded by the Council for the Arts at MIT.

Image and Imagination: 150 Years of Photography 23 September - 31 December

Our major concentration for the fall season, this exhibition surpassed the blockbuster show Bauhaus (1987) in viewer numbers. The exhibit's focus on the technical developments of the imaging process was praised by the media for its unorthodox approach in both content and presentation. A survey of photography's technological evolution and its concomitant product also highlighted the revolutions caused by the instant camera and electronic imaging systems. A separate section was devoted to both historically significant and contemporary photographers whose personal vision stretched the medium beyond conventional boundaries. Historical cameras and images were drawn from the rich lode in eighteen Greater Boston repositories. A joint effort of the MIT Museum and Polaroid Corporate Archives, the exhibition was accompanied by a lecture series and Saturday family workshop. Lectures included "The History of Photography" by Thurman Naylor; "How Process Formed Image," by Jim Dow; and "Photography: 20th Century and Beyond: The Advent of Electronic Imaging" by Richard Kee. The workshop, conducted by Elaine O'Neil, was titled "Imaging Your Imagination: A Hands-on Workshop in Photography." Images of New England: 1839-1989, a twenty page illustrated brochure provided by Polaroid, accompanied the exhibit.

Artists Behind the Desk 12 October - 12 January

A first-of-its-kind exhibition at MIT showcasing the versatility and talent of Institute support staff artists who support themselves and/or families through work at MIT. Professionally judged by three out-of-state art professionals, forty-nine works by 29 artists were selected for the exhibition.

AIDS: A Continuing Concern 1 December - 31 March

A special showing of panels from the NAMES Project AIDS Memorial Quilt, including one created for David Lewallen, a former MIT employee who succumbed to the disease, was held on World AIDS Day. The quilt section which included Lewallen's panel remained on exhibit until April. A video, which touchingly captured the heartache of those left behind, accompanied the Quilt panels. Lobby 10 was the locus of the MIT Museum's Quilting Bee to create a quilt honoring those members of the community who have died of AIDS-related conditions. Two illuminating photography exhibitions, works by Nicholas Nixon and a series by Linda Troeller, examined the disease's ravages and societal ostracism. Phoebe Hackett and Sally Beddow organized these events.

When the Eiffel Tower was New: French Visions of Progress at the Centennial of the Revolution 16 January - 25 February

The final decades in 19th-century France, rife with technological change, were represented by full-color posters, printed ephemera, journal illustrations, period photographs, as well as fine-art prints by Toulouse-Lautrec, Theophile Steinlen, Pierre Bonnard, and August Lepere. A special section of illustrations and informational text regarding construction technology used in erecting the

Eiffel Tower was added by the Museum. Five Eiffel Tower-related films were shown continuously. The exhibit and accompanying illustrated catalogue were organized and produced by the Mount Holyoke College Art Museum. Rosalind Williams presented the lecture "Paris 1990: The Technological Landscape of Modern Life."

Raumplan Versus Plan Libre: Adolf Loos and Le Corbusier 1919-1930 30 January - 1 April

Organized by the Technical University of Delft, the exhibit compared the spatial concepts of Loos' last productive years as an architect with Le Corbusier's first through photographs, plans, and models. An illustrated catalogue published by TU Delft provided additional insight.

Alchemical Reconnaissance 8 February - 6 April

Photographs by John Huddleston of Middlebury College juxtaposed the investigations of landscape photography with high energy physics. Landscapes were paired with formulations of concepts associated with particle physics. Huddleston's texts possessed the objective ring of textbook assertions, while his images fired the imagination to see these assertions as revelations.

Marcia Oakes Woodbury 14 February ongoing

Paintings and drawings by this turn-of-the-century artist whose style was popular in Boston. Celebrated in her own right, she was the wife of painter Charles H. Woodbury, Class of 1886.

Richard Bertman: Architect and Sculptor 15 March - 2 September

A diverse collection of sculptures, drawings, models, and plans by the eminent Boston architect (MIT Class of 1960 and principal designer of the Prudential Center renovation) whose critical accomplishments stand on view against the Boston skyline. Bertman's welded wire sculptures, described by Boston Globe critic Robert Campbell as "loony and funny, tense and affectionate," show influences of Calder, Saul Steinberg, and Alberto Giacometti. His architecture manifests his sense of playfulness and respect for craftsmanship and form.

From the Ecole to Tech: Desire Despradelle, His Colleagues and Students 23 March - 2 September

The architectural drawings of this Ecole-trained French architect, who headed the design course in MIT's Department of Architecture at the turn of the century, provide extraordinary examples of the Beaux-Arts aesthetic. Architect of the original Peter Bent Brigham Hospital, Despradelle's Berkeley Building has recently undergone an award-winning restoration. His primary influence was as an educator and drawings executed by several of his outstanding students were included. Guest curated by Kimberly Shiland, programs included "On the Work of Desiree Despradelle," gallery talk by Kimberly Shiland; "An Award Winning Restoration: Codman and Despradelle's Berkeley Building," gallery talk by James G. Alexander; "Ecole's Teaching Methods: Intentions, Implications and Consequences," lecture by Jean Paul Carlhian; and "The Atelier Pascal and the Ecole Des Beaux Arts," lecture by Richard Chafee. Support was received from the Council for the Arts at MIT, The Trustee of the Lowell Institute, G. H. Macomber Corp., and Notter, Finegold + Alexander.

Microscapes: The Hidden Art of High Technology 23 April - 2 September

Large format macrolens photographs shot at speeds as fast as 1/720,000th of a second and magnified as much as a billion times, show in breathtaking detail the unseen world of information and communication technologies developed by AT&T's Bell Laboratories. Such techniques as thermography, interferometry, color schlieren photography, and secondary ion mass spectroscopy create futuristic images of microprocessor chips, glass fibers, crystals, and magnetic bubbles. The exhibition was a gift from AT&T.

Other Exhibits and Programs

Earth, Sea and Sky, the work of Charles H. Woodbury, Class of 1886, acclaimed by the Boston Globe as one of 1988's ten best exhibitions, began a two-year, twelve-museum, cross-country tour.

Goin' Fishin': The Boston Fisheries 1900-1920, an exhibition of photographs, models, and equipment documenting Boston's fishing industry which had been on exhibit at the main facility October '88 - January '89, was installed at State Street Concourse Gallery from 12 October - 15 December '89.

Two exhibitions formerly shown in Compton Gallery were reinstalled at the main facility. Sculpture and paintings by Richard Filipowski, creator of the Form and Design Program in the School of Architecture and Planning, demonstrate spatial control through line, color, shape, and pattern. Stopping Time now occupies the Klimann Gallery and "Quicker 'n a Wink," Doc's Academy Award winning short film runs continuously. Several new plasma sculptures—one forty inches in diameter—have been added to Bill Parker's ongoing exhibit. The work of the Spatial Imaging Group at MIT's Media Lab has been moved to a more accessible location and is accompanied by a forty minute film which describes the principles and processes involved in creating various types of holograms.

The fourth annual exhibit of children's drawings was mounted in the Medical Department lobby. Paintings and sculpture from the Museum's collections were installed in the newly renovated Faculty Club and other Institute offices. Photographs from the collection were displayed at a Sustaining Fellows dinner for Harold Edgerton and at the Edgerton Jubilee. Electrical Engineering and Computer Science commissioned a photographic panel featuring the Robo-Puck competition held during IAP. Cibachrome prints

were framed for the Ocean Engineering Headquarters office. Our restructured and improved Bubble Machine was reinstalled in the lobby of Building 6.

COLLECTIONS

The MIT Museum Collections is a primary resource for materials related to MIT history and the Museum takes pride in presenting exhibitions and programs based on these collections. The Museum has presented the work of many MIT alumni and faculty, including Doc Edgerton, Constant Desiree Despradelle, Gyorgy Kepes, Richard Filipowski, Bill Parker, and Charles Woodbury.

As a service to MIT and the general public, the Museum collects materials that illustrate significant activities in MIT history, documents and cares for these collections, and provides access to information for research and publication purposes. Books on subjects ranging from artificial intelligence to computer graphics to finance have all included photos from the files. The Time-Life series "Understanding Computers" used Museum photos in most of their volumes. WGBH Public Television has utilized our collections for presentations on both radar, "Echoes of War," and computer history, "The Computer Age." Instruments and drawings were displayed in exhibits from Canada (Musée de la Civilisation in Quebec) to Oregon (the University Art Museum at the University of Oregon) and as close to home as the List Visual Arts Center. Over the year, the Museum fielded more than 500 inquiries.

The Hart Nautical Collections completed a number of major projects this year, most significant of which was the move of ship half models from Building 5 to the main facility. Other projects included the completion of the inventory of the Clark Collection of Marine Prints; a preliminary inventory of the Bethlehem Steel Collection of 15,000 plans, 55,000 negatives and archives from the Quincy Shipyards; computerized cataloging of various photograph and ship plan collections. With assistance from volunteers, preliminary research for an exhibit on whales in political cartoons, drawing from the Forbes Collection, was begun.

In FY90, the Museum received donations of technological models, instruments, illustrations, paintings, sculptures, and furniture. Videos, academic hoods, and professional awards have found a repository here, as well as uniquely MIT t-shirts and memorabilia. The Undergraduate Research Opportunities Program (UROP) asked the Museum to safeguard their twentieth anniversary time capsule.

During the year, the Collections employed the services of professional conservators Morton C. Bradley, Jr. for paintings and Sarah Riley and the Northeast Document Conservation Center for works on paper.

OTHER HIGHLIGHTS

ADMINISTRATIVE

- The Museum transferred administratively to the Associate Provost for the Arts.
- The Museum received its third Institute for Museum Services General Operating Support grant (\$74,438) for the coming fiscal year.
- The Museum was one of 100 museums selected for a Conservation Assessment Program \$5,000 grant, to be used for an appraisal of the Museum's collections.
- Personnel changes: Phoebe Hackett moved from part- to full-time Staff Accountant on July 1; Emmett Murphy joined the Museum as Shop Manager on January 1; Marcia Conroy, Assistant Director for Education and Public Relations, resigned in January, but has continued her association with the Museum as a consultant on specific educational programming; Kathleen Thurston, Museum Shop Coordinator for the last five years, is now Assistant Director for Marketing.

FACILITIES

As a service to the MIT community, the Museum makes available its facilities for departmental gatherings. In addition to nine exhibit openings, the Museum hosted thirty-seven functions for MIT departments and other groups in FY90. These events brought nearly 4,000 additional visitors to the Museum.

MUSEUM SHOP

The MIT Museum Shop produced two mail order catalogues which were sent to alumni and friends, and provided official gifts for representatives from many MIT departments who shopped at our two stores. Sales for the Museum Shop approached the half-million mark in FY90.

PUBLICATIONS

- This year, the long-awaited book on pranks and hacks at MIT moved one step closer to reality when underwriting was made available from the Peter deFlorez '38 Fund for Humor at MIT. It is set for October publication.

SEMINARS AND LECTURES

- Members of the Museum staff taught a Freshman Advisor Seminar on the history of the Institute for the second year. Three members of the staff also serve as freshman advisors.

- The director presented his popular lecture, "Traditions at MIT," to incoming students, parents and alumni groups. He also lectured on the history of the arts at MIT at a Technology Day seminar and presented the Lowell Institute School graduation speech.

- Graduate student Brian Liebowitz '82 presented his talk on pranks and hacks at MIT to several student and alumni groups across the country.

The MIT Museum Staff

Associate Provost for Educational Programs and Policy

Office of the Dean for Undergraduate Education (Committee on the Undergraduate Program, Undergraduate Education Office, Committee on Academic Computation for the 1990's and Beyond, Concourse, ROTC Programs)

INTRODUCTION

Five years ago the incoming Provost established the position of Dean for Undergraduate Education. This coincided with long-emerging faculty discussions culminating in a proposal from the faculty Committee on Educational Policy to seek just such an appointment, to reorganize the faculty educational and policy committee structure, and to call for the establishment of a locus of Institute oversight and expertise in educational studies and assessment.

The mission of the Dean is simply stated:

- o To address, with the faculty and appropriate Institute offices, the obstacles and discouragements faculty and departments identify as impediments to serious dedication to innovation, curriculum development, and high quality teaching and advising;
- o To promote a climate of "Why not?" and an excitement for experimentation and possibility by students and faculty;
- o To prompt and guide Institute-wide review: of its academic programs for their educational content and rationale; of the proper balance between research and instructional activities; and of the relation between undergraduate and advanced education activities. The most obvious manifestation of this review is the interlocking array of school, Institute, and departmental committees and experiments now underway. Quieter efforts, in different formats and schema, must also take place, involving the individual faculty member -- who must be encouraged and helped to undertake personal internal review of his/her professional dedication and goals within the institutional framework of priority for the undergraduate academic program.

There are two overarching emphases to this mission. The first emphasis pertains to the tone, content, form, and expectations of the undergraduate academic program. The faculty seeks to regain broadly-based agreement about the purpose of the undergraduate academic program and its intended audience. This effort is underway in the face of forces and demands which call into question whether MIT is any longer---or wants to be---spiritually-centered on undergraduates. The second emphasis is that of achieving a proper balance of faculty commitments between research enterprises, including postdoctoral education and graduate education, on the one hand, and undergraduate education, including non-classroom student life experiences, on the other.

Both of these emphases will require as much as a decade or more to address and are not amenable simply to curricular decisions or to academic legislation: these treat the symptoms, not the cause. The nub of things is MIT's own culture. It is here that the Institute's strengths and uniqueness lie. And it is here that the viscosity surrounding change is especially high. The past five years have served to prove that change is possible, to identify key issues and to build consensus that they are the right ones, and to prepare individuals to participate in these debates. It is encouraging that Institute-wide consciousness of these fundamental educational issues is now widespread and that an eagerness to address them is manifest. The next few months will provide opportunity to test the Institute's will to attempt serious change.

An essay laying out some of these matters was prepared for the NEASC accreditation team's visit in October. This essay, and the team's report subsequent to its visit, provide a clear window on current undergraduate education issues at MIT, and the stakes involved. The essay and report are recommended to the reader.

MARGARET L.A. MACVICAR
Dean

THE UNDERGRADUATE EDUCATION OFFICE

The Undergraduate Education Office (UEO) completes its third year as the active program arm of the Office of the Dean for Undergraduate Education. Responding to the evolving needs of the Institute, the office has this year aided and supported a variety of curricular efforts and administered its two academic programs, the popular Undergraduate Research Opportunities Program (UROP) and the Writing Requirement, an undergraduate Institute requirement.

UEO has this year continued to support faculty-student research, continued to work with departments which teach the freshman core curriculum, helped efforts to improve teaching, served as headquarters for the Context academic initiative, conducted and coordinated educational studies, aided the review of faculty involvement in Institute governance (i.e., Commons), and assisted the Dean, faculty and departments in myriad related efforts. Staff also represented the Dean on several Institute committees concerned with issues affecting undergraduate education.

Affirmative Action

One hire occurred this year, the position of office manager, for which there were no minority candidates among the seven interviewed, and none identified as minorities among the applicants as a whole. A female was hired.

With regard to minority undergraduates, the Hughes Medical Institute funding for UROPs in biology includes a portion for under-represented minority students, and for women, for a five year period. Dow Fellowships provided funding for four underrepresented minority students in chemistry, materials science and chemical engineering. The Department of Physics, using an earlier proposal developed by the UEO, is preparing a proposal for the National Science Foundation for funding for minority undergraduate research. A second proposal requesting support for minority students to work on research with MIT UROP students during the summer was submitted this year to the NSF by Nuclear Engineering faculty, but was turned down.

Academic Program: The Undergraduate Research Opportunities Program (UROP), 1969-1989

A twenty year anniversary was celebrated this year, and supporters and friends were invited to a party during IAP at which students' predictions about the future of their areas of research in the year 2020 were sealed in a time capsule and presented for safekeeping to the director of the MIT Museum. UROP continues as the oldest and largest of the proliferating undergraduate research programs nationwide. National representation in undergraduate research exists through membership on the National Conferences for Undergraduate Research Board; its fourth annual conference was held in the spring at Union College in New York.

A significant new source of support for undergraduate research came this year from the new Space Grant program, providing both term time salaries and summer positions with space industry corporations. Four fellowships for under-represented minorities were provided by Dow Corporation in chemistry, materials science, and chemical engineering. The New England, the Lord Foundation, and Sea Grant, among others, continue to provide financial support to undergraduate research.

The UROP student stipend held steady, currently equal to the current \$6.25 Institute minimum hourly student wage. On the other hand, reductions in sponsored research for faculty were reflected in increased demand for support from UROP for student stipends. This demand was offset in part by Hughes Medical Institute funding for biology research.

Participation in UROP increased during this year by eleven percent, the proportion of research done for credit from nineteen percent of all participation last year to twenty-one percent this year. The most significant change from ten years or more ago is the shift from credit to pay during term time. It is startling to recall that in 1979-1980 sixty-five percent of term time work was done for credit. By 1984-1985 this figure was down to forty-two percent. We fear that as celebrated and popular as UROP is, attitudes toward undergraduate research may have changed along with the shift away from credit, due to the intensive financial aid pressures now felt by parents and students. (In 1979, approximately 50% of the student body was termed Needy. In 1990, 62% are.) We are currently asking students and faculty for their thoughts on this point.

Academic Program: The Writing Requirement, Phases One and Two

The second part of the Writing Requirement, called Phase Two, has been administered since last year by the academic departments, each of which has a writing coordinator.

The Class of 1990 as a whole completed the Writing Requirement much earlier than preceding classes, indicative of a definite trend in completion time: Only thirteen percent of the Class of 1990 waited until the second term of their senior year to complete Phase Two, compared with thirty percent for the Class of 1989, thirty-eight percent for the Class of 1988, and thirty-nine percent for the Class of 1987. Partly responsible for this dramatic increase in timely compliance is the faculty's establishment of a new deadline for Phase Two completion. Students now must complete Phase Two by Registration Day of the term in which they hope to graduate. Students who fail to do so must petition the Committee on the Writing Requirement to be added to the degree list. The improvement in compliance may also be attributable to a positive change in attitude toward the Requirement on the part of many students.

The percentages of students employing each of three available options for completing Phase Two were roughly the same for the Class of 1990 as for the Class of 1989, with sixty-one percent completing Phase Two through writing cooperative subjects, twenty-eight percent by submitting a paper to their departmental writing coordinator, and ten percent by enrolling in a writing subject. Three members of the Class of 1990 were prevented from graduating solely because of their failure to complete the Writing Requirement, but all three are expected to complete it by September.

Much of the success of the Requirement can be attributed to the efforts of departmental faculty writing coordinators and the staff of the writing cooperatives in the Writing Program. We are working with departmental coordinators on ways to further improve writing instruction within individual departments. As part of this initiative, the Committee will meet next year with writing coordinators to discuss the Phase Two plans of individual departments.

Phase One is administered by UEO with Assistant Dean Les Perelman serving as coordinator. Students are asked to write two essays for the evaluation, the first on a primarily narrative or descriptive topic, the second a primarily argumentative topic. This year the latter essay was on the topic of homelessness, and related to the book freshman had been invited to read for R/O Week, *Rachel and Her Children* by Jonathan Kozol. The UEO and the Writing Program jointly sponsored a three-day IAP Phase One writing workshop, taught by Drs. Steven Strong and Katherine Burnett of the Writing Program with Dr. Perelman. The workshop was attended by sixteen students of whom eleven were able to produce an expository essay that fulfilled Phase One.

Public Education (K-12) Initiatives and Outreach

Interest has grown across the Institute in helping improve public education in science and mathematics. To this end, UEO has taken a lead in calling together faculty and staff to discuss their various education interests and concerns. UEO staff have also developed expertise on issues, programs and standards in the field.

We are currently assessing the relative merits of developing a teacher training or related program at MIT to ensure that undergraduates seeking the opportunity to teach will have the support and guidance they need. MIT has long had access to Wellesley College's teacher certification program through the Wellesley-MIT Exchange. This year access was improved by making it possible to hold one of Wellesley's education courses at MIT. In the coming year MIT's developmental psychology course, a basic requirement for teacher training, will be offered by Professor Susan Carey. In addition to obtaining easier access to the Wellesley program, MIT undergraduates may now enroll in the Undergraduate Teacher Education Program at Harvard's Graduate School of Education.

Two mailings made this year to undergraduates about possibilities that exist for those interested in teaching resulted in inquiries from more than a hundred students. Wellesley's program staff are preparing for an increased MIT enrollment, already visible in the introductory classes, and Harvard's program expects some five to ten MIT students this coming fall.

Conversations were held with the Massachusetts Department of Education and the Cambridge school system concerning various approaches to teacher training and/or classroom observation and the requirements for a formal teacher certification program. While there are no plans for such a program at this time, the groundwork has been laid for consideration of all the various alternatives. We hope that next year will see further building and coordination of MIT's efforts for public education.

The Context Support Office and Context Initiatives

UEO was involved for the third year in assisting the Committee on the Undergraduate Program (CUP) sanctioned experiment "Human Contexts of Science and Technology." The Context Review Group, chaired by Professor Francis Low, submitted its recommendations in July and, following discussions among faculty in departments, schools, and at the October faculty meeting, the second phase of the Context experiment began. Professors Lawrence Lidsky and Merritt Roe Smith were named co-directors of the initiative, and the support office was established within UEO with seed funds from the Schools of Engineering, and Humanities and Social Sciences, with additional help from the Dean for Undergraduate Education. The office is to serve as catalyst for the incorporation of contextual studies and approaches in established MIT subjects and programs.

Over the past year, a number of successful events were sponsored, following the Context Review Group recommendation that we strengthen and publicize activities at the Institute that already address cross-disciplinary areas. Notable among these was a well attended faculty forum moderated by President Gray on the topic, "Should MIT Try to Influence Public Policy?" In April the office co-sponsored an all day forum run by two graduate students on "Error, Fraud, and Misconduct in Science." We would like to see more students -- graduate and undergraduate -- organizing activities like this and hope to cultivate student initiatives over the coming year. Plans are in the works to co-sponsor (with the Undergraduate Association) a regular series of topics on contemporary affairs. Most departments and a number of programs contributed to our compilation of subjects, seminars, and programs offered each term that are cross-disciplinary and contextual in nature, titled "Technology, Science, and Contemporary Affairs."

During the spring term the office sponsored an Undergraduate Seminar on MIT and its environment, bringing together an enthusiastic group of students with members of the Physical Plant Department. At least one interdisciplinary research project will result from this term's seminar, as well as the possibility of beginning a student internship program with Physical Plant.

The existing Context subject program continued with the majority of offered subjects well received, although two were cancelled due to low enrollments. Plans have begun for two activities that will take place during the next academic year. A "People Mover" design contest will be announced in the fall, motivated by our observation that when it is made easier for faculty to meet, interdisciplinary projects flourish. Mini-courses for faculty are also in the works, including one for IAP entitled, "The Art of Engineering."

Science Core Coordination and Related Activities

The Departments of Mathematics and Physics continued their collaborative activities for the freshman science core subjects with our assistance. In September the departments held a joint orientation session for instructors new to MIT and/or new to teaching. The session provided information about the content and pace of the various subject options, the undergraduate experience in general, and a discussion on teaching techniques for first time instructors. In addition, participants viewed a videotape of sample segments from typical lecture and recitation sections, and were given an opportunity to meet and talk with experienced instructors.

Students in the mainstream physics subjects -- 8.01 in the fall and 8.02 in the spring term -- were assigned to one of two groups of recitation sections according to their math enrollment (called "tying"). This arrangement continues to be popular with the physics recitation instructors, as it enables them to work with a group of students with more uniform mathematics backgrounds. In addition, a number of paired recitation sections in mathematics and physics each contained a common group of students ("linked sections").

The office coordinated an ongoing series of meetings between lecturers and section instructors in all core math and physics subjects. Lecturers met at the beginning of each term to exchange syllabi and plans for the semester. Recitation instructors were invited to come to meetings chaired throughout the term by Professors David Jerison and Robert Redwine, and organized by UEO. Attendance was excellent (eighty-five percent of the teaching staff attended at least one meeting), and the instructors were able to provide valuable feedback on curricular and teaching issues to members of the Admissions Office, the Committee on Undergraduate Admissions and Financial Aid (CUAFA), and the Undergraduate

Academic Support Office (UASO), as well as to their departments. Next year these meetings will be expanded to include instructors in the core chemistry subjects (3.091, 5.11, and SP.01-SP.02).

In another cooperative UASO/UEO project, staff are working together to enhance the freshman year orientation program by involving science core lecturers in informal meetings with students as they prepare for their first classes.

We routinely distribute syllabi and enrollment information for all the freshman science core subjects to all the lecturers of those subjects. The UEO assisted in the coordination of quiz dates by collecting and circulating tentative schedules several times before the start of each term, and by coordinating conflict resolution. End of term performance statistics are also routinely assembled and appropriately distributed.

The physical plant has now assumed responsibility for overseeing core subject blackboard cleaning, begun several years ago by UEO on a pilot basis. Program Administrator Maureen Horgan continues her oversight role.

Meetings were organized to prepare the 1990-1991 core lecturers for the new pass/no record grading scheme where D is no longer a passing grade for freshmen. Two of the meetings were chaired by the Dean for Undergraduate Education. UEO and UASO staff met with recitation instructors to discuss how the evaluation system could be adapted to provide better feedback to students on their progress through the science core subjects, and are also working with the departments to improve the performance evaluation system by involving recitation instructors earlier and more directly with students having academic difficulty.

Faculty Development Activities

For the second year staff members met with all new members of the faculty to talk about their impressions as new members of the educational community, and offer assistance where appropriate. As was the case last year, these visits provided insight into the way new members of the community react to MIT, particularly with respect to the undergraduate program. We are considering ways to share these impressions for the benefit of future new faculty.

Ms. Horgan provided administrative support to the School of Engineering Faculty Instructional Resources Program (FIRP) in its effort to provide teaching effectiveness feedback to faculty through the videotaping of classes, a program made possible by the support of Dean of the School of Engineering Gerald Wilson and Director of the Center for Advanced Engineering Study (CAES) Professor Shaoul Ezekiel. Classes were videotaped by the Video Production Services of CAES. Faculty members received the tape to view privately or with a colleague. Twelve faculty took advantage of this service in the spring term, the first term it was offered.

Meetings of Undergraduate Academic Officers

All departmental undergraduate academic officers were invited to meet under the sponsorship of the UEO so that they could hear from faculty committee chairs about on-going educational reviews, and the committee chairs could solicit information and opinions from departments before deliberation or planning was completed. The meetings, held regularly each year, provide one of the few opportunities for faculty education officers to share concerns about general issues relating to the curriculum, the advising system, and the like, and meet on an informal and collegial basis.

Educational Studies

The Privacy Committee in its 1989 report to President Gray cited the lack of organizational responsibility for educational studies data, and the CUAFA report of last year recommended "institutional encouragement and support for coordinated educational studies." To mitigate this dispersion of interests and lack of coordination, the Dean asked UEO to bring together those who share an interest in gathering educational data and conducting studies of the undergraduate experience. The Educational Studies Working Group, a group of professionals concerned with or involved in research of the educational process, has continued to meet this year, and is increasingly being looked to as a source of shared expertise. It worked this year on discussing issues related to privacy among others, and will continue next year focusing on educational research issues of mutual concern.

Studies have nonetheless been conducted by UEO staff, for the most part on an ad hoc basis. In spring 1989 a review of the new experiment-based physics 8.02X course was made at the request of the Physics Department. This year UEO Director Norma McGavern and Professor Benson Snyder were asked to review the new fall 8.01X course. In addition, UEO was asked to undertake a sampling of student opinion about the new jointly taught SP.01-SP.02 course which combined material from materials science, chemistry and biology, information intended to aid the Committee on the Science Requirements.

The Interview Project of the Class of 1991 continued with a third year of interviews with students from the Class of 1991 under the supervision and administration of Professor Snyder and Assistant Dean Margaret Richardson Enders. The project provides an opportunity to have an ongoing, reliable and up to date "picture" of a class of students as they proceed through their years at MIT, offering information about students' attitudes and opinions of classes, instructors, academic advice, etc. Of the original fifty students randomly selected at the start of their freshman year, forty-six were interviewed during their first year, and most of the group has been interviewed once each year since then. During the past year, coding of the sophomore interviews and the third round of interviews with students as juniors was completed, the latter with the assistance of sixteen staff volunteers from all the freshman-related support offices (UASO, the undergraduate offices in humanities, chemistry, math, physics, Admissions, Concourse, ESG, and the Registrar's Office). Some preliminary work has begun on an analysis of the students' reports on their experience with the MIT workload. We hope the forthcoming year will provide the opportunity to study this issue in more depth.

Once again we assisted Associate Provost Jay Keyser with his informal survey of the Classes of 1989 and 1990 through letters written to all seniors at the end of their spring terms. This year students were given the chance to respond to Professor Keyser via Athena e-mail. It is clear that, although the responses from students may be too few to be considered a representative sampling since only about fifty students respond yearly, the thoughts and opinions of those students who do write are often compelling, sometimes disturbing, and always useful in stimulating discussion about the undergraduate experience.

Study of Student Workload

The UEO is working together with the CUP, the Committee on Curricula (COC), the UASO, and the Undergraduate Association's *Course Evaluation Guide* to study the relationship between the subject units listed in the MIT *Bulletin* and the number of hours MIT undergraduates actually spend on those courses. Joseph Wang, '92, *Evaluation Guide* staff member, compiled data from the past three years' student course evaluation forms concerning hours

spent on MIT subjects, and prepared a preliminary study on the differences between the average amount of actual time reported and official credit hours. An outline of the effort to assess actual time spent on academic work and a preliminary presentation of the data were presented at a meeting of the Undergraduate Academic Officers in January by Dr. Perelman, Fumitomo Hide, '92, and Mr. Wang.

Unfortunately, since *Evaluation Guide* forms have been ambiguous in differentiating between homework and laboratory hours, some of the data has been unreliable, especially that data coming from subjects with laboratories. *Evaluation Guide* staff have corrected the forms, and in spring 1990 more accurate data was collected. The UEO is analyzing the information, and expects to report results to academic departments, the COC, the CUP and other appropriate Institute bodies. Dean MacVicar and Dr. Perelman met with the COC on the issue of student time use, and that committee and UEO are considering conducting their own pilot study.

The Commons Initiative

With the hope of integrating those undergraduate educational activities common to the Institute as a whole into already established departmental and school planning procedures, the CUP in 1988-1989 began what has become known as the Commons initiative. The Commons planning process consists of reporting past faculty participation to department heads and school deans so that faculty can receive proper credit for their contribution, seeing that current urgent needs from activities are reported to departments, and, in the fall, distributing a list of the number of faculty needed for each activity in the coming academic year.

During the past year the UEO took on the administrative support of Commons, collecting data on participation from the various undergraduate activities and helping prepare the Commons report sent to school deans and department heads in January. A report on the Commons initiative was made to the CUP in December and again in April. Dialogues and discussions concerning improved faculty participation and obtaining more accurate data are ongoing.

Other activities

Relations between MIT and the Harvard Cooperative Society improved considerably following the liaison effort mounted last year by the UEO in response to faculty dissatisfaction with book ordering and delivery performances by The Coop. Improvement continues with The Coop reporting a significant increase in the number of spring term book orders, and a dramatic decrease in faculty complaints.

Efforts continued to help facilitate contacts between reference librarians and faculty teaching humanities distribution (HASS-D) subjects so that library materials will be more accessible to students. Dr. Perelman and acting humanities librarian Theresa Tobin attended a conference on bibliographic instruction conducted by Earlham College which resulted in a workshop for the Institute's public service librarians on ways to improve classroom use of the MIT libraries.

Institute Committees

The Dean for Undergraduate Education was represented on a number of Institute committees by staff of UEO, including the Committee on Curricula (COC) by Ms. Enders, the Committee on Admissions and Financial Aid (CUAFA), the Committee on Academic Performance (CAP) and the Committee on the Writing Requirement by Ms. McGavern. Additional support this year

was given by Ms. Enders to the newly-established Committee on the Science Requirements chaired by Professor Hartley Rogers, and having representation from all MIT schools. It is currently reviewing a number of aspects of the science core requirements, and has been charged with evaluating the SP.01-SP.02 experiment. The ROTC committee, also supported by Ms. Enders, was a demanding assignment in the spring and may continue to be so in the coming year.

Personnel

Staff reporting to the Dean for Undergraduate Education include Ms. Norma McGavern, UEO Director since January 1989, Assistant Deans Margaret Richardson Enders, Les Perelman and Jane Sherwin, Program Administrator Maureen Horgan, Office Manager Ms. Cynthia Rose who completed her first year with the UEO in January 1990, and Senior Staff Assistants Ms. Robin Pachtman, and Ms. Stacia Conklin Kraft.

Associated with this office is also Ms. Cheryl Butters, Concourse Program Administrator, and Professor Robert Rose, Concourse Director. Professor Benson Snyder, tenured in the Office of the Provost, retired officially from the Institute this June, although he will continue his association with this office for another year as Professor Emeritus. He has consulted and worked regularly with UEO staff, primarily with regard to issues of educational research. Dr. Gregory Jackson, an adjunct staff member and Special Assistant to the Dean, worked this year as professional support to the Committee on Academic Computation for the 1990's and Beyond (CAC). Ms. Rose aided Dr. Jackson on CAC work throughout the year.

With Ms. Sherwin seeking a new direction for her career, we find ourselves about to search for a Program Administrator to assume the duties of running the day-to-day operations of UROP, under the guidance of Ms. McGavern.

Our regular staff was considerably aided and abetted this year by our student workers Jason Satterfield, '90, and S. Madhavi Gupta, '93, both of whom will stay beyond June 1990 to help us in the summer, by Kevin Hwang, '91, Deborah Wells, '92, Crystal Lawson, '90, Hina Ansari, '93, Kenneth Schneider, '92, Jeff Fabijanac, '92, and Soo-Ah Kim, '92. We are grateful to graduate student Ann Bumpus for her conscientious computer support, carried out with grace and tact. We are also grateful for the long term, good spirited temporary support provided by Mr. Jonathan Larsen who will embark on his career this coming summer.

The 1990-1991 academic year will, at last, find UEO staff in rehabilitated and larger quarters within building 20, and with a slightly amended address (20B-140 instead of 20B-141). As the present academic year ends construction work is poised to begin.

NORMA G. MCGAVERN
Director

THE COMMITTEE ON THE UNDERGRADUATE PROGRAM

The Committee on the Undergraduate Program (CUP) fulfilled monitored and prodded into action various initiatives and experiments. A subcommittee was formed to construct language for Rules and Regulations of the Faculty and devise implementation plans regarding pass/no record as voted by the Faculty in May 1989. A report on the status of design plans for a biology requirement was heard, a topic that CUP will take up next year.

The Committee initiated discussions on the implications of Pass - C for advising, subject planning, and R/O.

The annual Winter Work Session entitled "Who are We?" focused on the diversity of the MIT community. CUP members and several guests heard presentations on the MIT community, the student body (admissions and financial aid aspects), and activities both in and out of the classroom. The day was highlighted by lunch discussions in small groups with students representing a broad spectrum of backgrounds and interests. The concluding session summarized the lunch discussions and outlined ways to continue exploration of the topic of diversity.

CUP endorsed a proposal submitted by the School of Humanities and Social Science to eliminate level IV language subjects from the HASS-D system and to establish a Language One Option that allows students to substitute one language subject at the level of III or IV for one HASS-D subject.

As has been its custom, CUP requested reports from several committees and individuals throughout the year. These included the following:

- Dean McBay briefed CUP members on programmatic changes in the Interphase Program and the establishment of the Excel Program.
- The Context Review Group, chaired by Professor Francis Low, presented its conclusions about the Context notion. These included unanimous and enthusiastic support for the Context notion as an important component of an MIT education for undergraduates, graduate students, and teachers. The group urged the continuation of Context subjects and programs and offered recommendations for doing so.
- In compliance with the motion voted by the Faculty in May 1987, the School of Humanities and Social Science gave its annual HASS-D implementation status report. New HASS-D subjects are being offered, old courses have been restructured or removed from the list, and the balance of offerings across the five categories is improving. Also noted was the progress made in offering minor programs in HASS.
- CUP discussed the recommendations of the Freshman Housing Committee with its chair, Professor Molly Potter. These included preassigning freshmen to housing on campus before orientation, adding to the number of beds on campus, and improving programs related to residential life.
- The Committee was updated on Project Athena and work by the Committee on Academic Computation for the 1990s and Beyond.
- The Committee on the Science Requirements informed CUP of its intent to assess the pilot programs and develop recommendations to the Faculty for inclusion of biology in the Science Component of the General Institute Requirements, to review the objectives of the Science Distribution and examine the list of individual subjects to insure that the Science Distribution fulfills its purpose, and to review on an ongoing basis the content and appropriateness of the Science Component of the General Institute Requirements.
- Progress on establishing an Institute-wide planning system for educational commons activities was reviewed twice.

- A proposal to extend the fall and spring semester final exam periods to five days with related calendar changes was considered. Recommendations were made before the proposal was presented to the Faculty for a vote.
- The IAP Policy Committee reported on its deliberations, finding that IAP is a viable enterprise that should continue, that students have responded positively to credit-bearing offerings, and that faculty participation is not at a sufficient level. The committee made several recommendations.
- Informational discussions took place concerning ROTC on campus and the military's policy on sexual orientation. Commanders of the MIT ROTC units joined CUP for a meeting.
- Professor David Wormley presented progress reports on a proposal submitted to the National Science Foundation for a program to renew undergraduate engineering education and to attract more students into the field of engineering, particularly women and minority students.

CUP bid farewell to departing members Professors Philip Khoury, Kenneth Manning, and David Gordon Wilson, Dean Shirley McBay, and Mses. Anne Louit and Deborah Nungester (undergraduate student members).

LAURA B. MERSKY
Secretary to CUP

COMMITTEE ON ACADEMIC COMPUTATION FOR THE 1990'S AND BEYOND

The charge to this Committee from the Provost was to consider and recommend options for academic computing following the experimental period for Project Athena, which ends in June 1991. The eighteen members of the Committee, which is chaired by the Dean for Undergraduate Education, are from the five Schools, from academic-computing organizations, and from the undergraduate and graduate student bodies.

The Committee began work in June 1989. It met for well over 100 hours throughout the year; made site visits to three other universities; consulted widely with various constituencies at MIT, including Project Athena's external partners; and reviewed extensive materials on Project Athena, other computing at MIT, and academic computing elsewhere.

The Committee began its work with a set of principles for academic computing. These yielded a series of discussion outlines, which became more specific as data and findings accumulated. The Committee sent a summary of its discussion to Schools and a sample of faculty members in the fall of 1989. In December it met with liaison teams from each of the five Schools, the MIT Libraries, and the undergraduate student body.

In the early spring of 1990 the Committee prepared a background paper, Computation and Educational Community, which circulated widely within the Institute. Members of the Committee met with representatives from each School -- its Council, in several cases -- and from other constituencies. In addition, several faculty members and senior officers of the Institute commented individually on the background paper's preliminary recommendations.

Based on the background paper and responses to it from the MIT community, the Committee wrote a Final Report, Computing for Education at MIT, and submitted it to the Provost in mid-June. In this Report, the Committee concluded that academic computing is an essential component of a modern research and teaching university such as MIT -- essential not only to maintain the Institute's current standing in education, but to move it to new, innovative levels of excellence. In particular, the Committee calls for a reorientation of MIT academic computation toward the user, and away from being designer-driven. The Committee recommends 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.

The Committee suggested that the Provost appoint one or more implementation/decision teams to elaborate and refine its recommendations during the summer of 1990. The Committee plans to reconvene in the fall to review the work of these teams, and to disseminate its findings and recommendations more widely within the MIT community and elsewhere.

GREGORY A. JACKSON
Study Director for the Committee

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 coordination of the core material, which shows the connections between the sciences, technology and the humanities, and facilitates learning through reinforcement.

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 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 of Concourse students in student leadership positions at MIT.

Statistics

Sixty-three students enrolled in Concourse for the fall term. Of these, 32 were male, 31 female, 51% and 49% of the total respectively.

Twelve of these students (8 male, 4 female) were minority students, 19% of the total enrollment.

The spring semester had a total of 53 students, 26 male and 27 female, including in the total 7 minority students (13%).

With regard to academic performance, the Concourse Class of 1988-89 performed, in its sophomore year, approximately as well as the Class of 1992 on the whole, although the scholastic indices for the Concourse Class of 1988-89 as entering freshmen were significantly below the mean for the Class of 1992 on the whole. We tabulate these data below:

COMPARISONS OF ADMISSIONS STATISTICS AND ACADEMIC PERFORMANCE DURING SOPHOMORE YEAR FOR CONCOURSE CLASS OF 1988-89

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	47	54	3.4	4.0*	3.95**
Students enrolled in Concourse for Fall Term only	18	54	3.3	3.75***	3.75****
Other MIT First Year Students	829	61	3.5	4.0	4.2

*Data on only 46 students. Seven students (15%) were flagged for discussion by CAP.

**Grade point data on only 44 students. Six students (14%) were flagged for discussion by CAP.

***Grade point data on only 16 students. Four students (35%) were flagged for discussion by CAP.

****Grade point data on only 16 students. Two students (8%) were flagged for discussion by CAP.

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 (1988-1989; MIT Class of 1992) entered the following disciplines:

28 students (61%) entered departments within the School of Engineering;
 12 students (26%) entered departments within the School of Science;
 1 student (2%) entered departments within the School of Architecture and Planning;

2 students (4%) entered the School of Management;
1 student (2%) entered a department within the School of Humanities and Social Science;
2 students (4%) remained undesignated.

Of the engineering majors, the most popular department was Electrical Engineering and Computer Science (ten students) followed by Mechanical Engineering (nine students), Aeronautics and Astronautics (five students), and Chemical Engineering (three students). In the School of Science, there were six Biology majors and three Physics majors. The remainder were spread out evenly, with one or two students per department.

Faculty and Staff

Members of the Concourse Faculty for 1989-90 were: Professor Robert M. Rose, Department of Materials Science and Engineering; Professor Judah L. Schwartz, School of Engineering and Harvard School of Education; Dr. Ross L. Finney and David Yavin, Department of Mathematics; Dr. Edwin F. Taylor, Department of Physics; Dr. Gilbert Whittemore, MIT Writing Program; Professor Henry C. Finney, Writing Program and Department of Sociology at the University of Vermont; and Massimo Russo, Department of Mechanical Engineering. 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.

ACADEMIC DEVELOPMENTS

Humanities

"The Scientific Revolution," 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, 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.

Concourse presented a new HASS-D course entitled SP341, "Art and Society." The course surveyed the social contexts of the production, distribution and consumption of visual art in modern America, along with selected social problems in the arts. Students in the course enjoyed a variety of visits to locations in the Boston art world, including gallery presentations by curators at the Institute for Contemporary Art and the List Center for the Visual Arts. Several representatives of the local art world addressed the class. Students also made art works of their own in response to a major social problem of their choice culminating in a student art show at the end of the term.

Concourse Elective

In the fall term, with 37 students registered, the elective was conducted in the form of lecture/discussion sessions, with three problem sets assigned during the semester. The material covered the construction (and inadequacy) of models in science, approximation

techniques, algebraic models in physics and chemistry, equilibrium and temporal evolution, and uncertainty (statistical, quantum and chaotic). The objectives of the course were to serve as a "super-recitation" for physics, chemistry and calculus; to demonstrate to the student the limitations of the scientific approach; and to make the student reflect, on a meta-level, on the models used in his scientific training. In the spring term the course continued as a small seminar with only four students. The focus was the construction of computational models using computers; the models were the physiology of "jet lag" and a spatially dependent predator-prey model. There were some areas where the lack of success was notable: the idea that science falls short of absolute reality caused notable discomfort; the peripheral nature of the subject (relative to the core subjects) led the students to limit their commitment outside of class hours (although class discussions were spirited and intense); and the students' facility with computational techniques was sufficiently fragile that it was difficult to focus on the models themselves. In many senses these difficulties led to the activities described below.

Extracurricular Educational Activities; IAP

As a result of student input (and our experience in the Elective), a series of half-day sessions were held during IAP which dealt intensively with the solution of scientific and technical problems. The problems usually involved chemistry and physics and were related to standard material covered in the Fall Term; some were abstract, but most were quite practical. Many were on the level of a difficult homework assignment. Some were much more difficult, and some were not soluble except by approximation. These activities were met with intense and sustained enthusiasm on the part of the students, despite the level of difficulty. There were two objectives for this activity: improvement of analytical skills, and the construction of scientific and technical models (an essential part of the problem-solving methodology), in essence the same objectives as the Concourse Elective, but approached from the opposite side. The success of the "anti-Context" approach was discussed at the regular dinners held in the Concourse Lounge during IAP, and plans were made for continuation and expansion of these activities.

An immediate result of our findings was the inauguration of the weekly "physics breakfast" where the sort of activities described above were continued throughout the spring term.

Science Core

The core presentations continue the successes of previous years. In the first term physics and calculus are coordinated, with some instruction in common, for instance in graphing and roots and the solution of first-order differential equations. Two areas of traditional conceptual difficulty, scalar and vector fields and normal modes of oscillation are emphasized. The physical problems from which calculus developed are presented. The objective is to provide the analytical tools to facilitate 18.03 Differential Equations and 8.02 Physics II. Experimental 8.02X "take-home" kits were tried out by 20 volunteers, who reported considerable enrichment of their understanding of electromagnetic phenomena. 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

CHERYL BUTTERS
Program Administrator

RESERVE OFFICERS TRAINING CORPS (R.O.T.C.)

At the request of the Dean, an ad hoc review committee, headed by Professor Kim Vandiver, reviewed the MIT-ROTC partnership to identify areas needing attention and improvement. The committee's report was received in October, helpfully ahead of springtime events prompted by the Navy's disenrollment of an undergraduate midshipman due to his gender orientation. The presidential standing committee on ROTC was reconstituted in the spring to act on the agenda of issues identified by the ad hoc review committee. Chaired by Professor Alvin Drake, the standing committee also serves as the primary campus body to deliberate the future of the MIT-ROTC partnership in the face of DOD policy discriminating against homosexual orientation.

In March the Dean, the senior MIT officer overseeing ROTC, issued a public statement questioning the appropriateness of ROTC programmatic presence on the campus in the face of MIT's own anti-discrimination policy. The Provost corresponded directly to Secretary Cheney, Department of Defense, concerning the harsh recoupment decision levied on the disenrolled undergraduate midshipman; in response, DOD reversed its recoupment decision. At the May faculty meeting, a resolution was passed to pursue changes in the discrimination policy of the military with regard to gender orientation according to a timetable that could include eviction of ROTC from the campus if the effort fails. The standing committee was asked to develop a suitable timetable and plan of pursuit, and to bring these back to the faculty in AY 90/91 for approval.

The Dean has requested that all incoming ROTC students be notified that institutional review of the incompatible ROTC-MIT discrimination policies is underway.

MARGARET L.A. MACVICAR
Dean

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 lieutenants in the United States Air Force. Year-end enrollment in AFROTC as of June 1990 was as follows:

	FRESHMEN	SOPHOMORES	JUNIORS	SENIORS	TOTAL
MIT	25	18	16	29	88
Harvard	0	3	4	2	9
Tufts	2	6	7	1	16
Wellesley	4	0	0	1	5
Total	31	27	27	33	118

This year, the AFROTC program provided MIT cadets with over \$1.2 million for tuition. All but 6 of the MIT cadets were on an AFROTC scholarship. Cadets from the other schools received tuition payments exceeding \$.35 million. In addition, payments for textbooks and subsistence exceeded \$.13 million.

Several special cadet activities highlighted this year's training for AFROTC students. The Arnold Air Society (AAS) Squadron, a professional honorary service, participated in local and national conventions, performed community service and awareness function/events, and participated in fund-raising efforts for local charities. Our AAS squadron was the area headquarters for the 89/90 school year, responsible for coordinating and administering all AAS activities for Northeast area units. The Blue Eagles cadet drill team and the cadet color guard represented AFROTC in local parades and ceremonies. Other cadet events included the annual Tri-service Awards Banquet and the Military Ball. LT General Gordon Fornell, a commanding officer at Hanscom Air Force Base, spoke to the cadet group at a formal dinner in November. The year concluded with the traditional commissioning at the USS Constitution.

29 MIT senior cadets received commissions as second lieutenants in the Air Force. One of these will go on to pilot training and two will go to navigator training. In addition, eight of these lieutenants were offered the opportunity to pursue advanced degrees before entering active duty.

Colonel Gary G. Nelson, AFROTC detachment commander, departed on 1 June 90 and Major Brian K. Mazerski will depart on 5 September 90. Major Ray Levias and Captain Charles D. Barondes completed their second year of dedicated service at MIT.

COLONEL GARY G. NELSON

Army ROTC

The 1989-90 Academic Year was another productive one for the Army Reserve Officers' Training Corps (ROTC) program. However, overall enrollment was off from past years. Over the academic year, a total of 93 students participated in our program, and at year's end, 81 of those students were still enrolled. Of the 81 cadets, 21 (25%) were females, indicating our support for Affirmative Action.

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

	FRESHMEN	SOPHOMORES	JUNIORS	SENIORS	TOTAL
MIT	4	15	11	9	39
Harvard	2	9	7	6	24
Tufts	3	2	6	1	12
Wellesley	2	1	0	3	6
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
Total	11	27	24	19	81

Of the 39 MIT students enrolled, 30 are currently recipients of Army ROTC scholarships, and five others have scholarships pending. These scholarships pay 80% of tuition and fees; provide a monthly allowance of \$100; and contribute once-a-year textbook allowance of \$370. The value of these scholarships to MIT for school year 1989-90 was \$540,000. We anticipate that for school year 1990-91, approximately 34 MIT cadets will be on scholarship with a value to MIT of approximately \$408,000.

This year the Army ROTC Department commissioned 18 new second lieutenants, eight of whom were from MIT. Of the 18, four are entering graduate school, eight will be reporting immediately to active duty, and six are serving in the Army Reserve. We achieved our commissioning mission from our higher headquarters of 18, and expect to exceed it for school year 1990-91.

During the year, Army ROTC again sponsored the Annual Tri-Service Awards Banquet with over 100 cadets receiving awards from 45 different organizations. Representatives of the MIT, Harvard, Tufts, and Wellesley administrations attended the banquet. Captain Francis H. Huron, USN (Ret), SM, 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, with President Paul Gray participating.

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. Members of the committee, along with other members of the faculty and Lincoln Labs, also participated in over 20 scholarship boards throughout the year. The professional evaluation of scholarship potential rendered by members of the MIT community will be of great value to each applicant and to the Army.

MAJOR RALPH GABRIEL

Navy ROTC

The Navy Reserve Officer Training Corps (NROTC) program at MIT provides challenging and comprehensive leadership and academic training for students attending MIT, Harvard, Tufts and Wellesley universities. Our program encourages academic achievement, while providing practical experience, to provide the Navy and Marine Corps with intelligent and capable officers. During the 1989-1990 academic year, we increased participation in university activities and expanded our community outreach and professional development programs. After four years of intensive study and training, 31 men and women were commissioned into the Navy and Marine Corps. Several members of the senior class were allowed to pursue graduate study prior to their commissioning. A breakdown of enrollment as of June 1990 follows:

	FRESHMEN	SOPHOMORES	JUNIORS	SENIORS	TOTAL
MIT	27	19	21	18	85
HARVARD	15	15	11	11	52
TUFTS	11	9	10	11	41
WELLESLEY	2	1	0	0	3
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
TOTAL	55	44	42	40	181

The Navy's financial support for these students included tuition, book and stipend payments totaling over \$2.7 million for the year. Payments for MIT students totaled \$1.35 million. In addition to their instructional duties, the Navy staff provided academic counselling, professional guidance and advice to supplement that available through other university offices.

Several of the professional development opportunities available to NROTC midshipmen included:

Offshore Sail Training program - This program provides exposure to a nautical environment, training in watchstanding fundamentals and application of practical military organization on the unit's 41 foot sailboat Patriot. In addition to the academic year program, the unit sponsors two intensive three-week sailing cruises around Cape Cod and the Islands for interested midshipmen.

Semper Fidelis Society - This society promotes the ideals and physical fitness regimen required to be a Marine Corps Officer. Field trips, guest lectures and group workouts provide interested students with the background to excel in the Marine Corps.

NAVTAG - The Navy Tactical Game provides realistic, computer-generated operational scenarios for teaching midshipmen the weapons/engineering capabilities of U.S. and Warsaw Pact naval platforms.

Field Trips - Field trips provide practical exposure to military operations. The unit's location in the center of a defense related research area offers exposure to the workings of support facilities and the cutting edge of technological innovation. Several trip highlights included the commissioning of the USS Normandy (CG-60) in Newport, RI, a tour of the Trident Inertial Guidance Labs at Draper Laboratory, a tour of Spears Associates,

Inc. to learn about submarine communication technology, a tour of one of the Navy's newest minesweepers, USS Defender (MCM-2), and repelling and land navigation training at Leominster State Park.

The unit continues to be an active member of the MIT and Greater Boston communities. A sail training program was started with the NJROTC students at West Roxbury High School to expose them to the rigors of sailing, promote teamwork and encourage pursuing further education for personal and professional rewards. Training consisted of lectures at the school and a "hands on" portion conducted underway on the PATRIOT. Staff members assisted local high schools by attending career information sessions to provide details about the NROTC program for interested students. The Battalion participated in both Veterans and Patriots Day parades, favorably representing the Navy and MIT to the public. For a community service project, members of the Battalion volunteered to spend a day working at the Vietnam Veterans shelter on Long Island in Boston Harbor.

The Navy sponsored the annual Tri-Service Commissioning Ceremony aboard the USS Constitution. President Gray and Professor Drake joined Rear Admiral David M. Goebel, Deputy Director International Negotiation JCS, our guest speaker and Commissioning Officer, for the ceremony. The new Ensigns and 2nd Lieutenants will represent MIT in the Surface, Aviation, Nuclear power, Special Warfare (SEALS), Supply, Intelligence, Civil Engineering Corps, Marine Corps, Naval Reactors and Cryptography communities. Other activities included our Freshmen Orientation program at Ft. Devens, Marine Corps Birthday Ball, Tri-Service Military Ball, Tri-Service Awards Banquet and an active program of Tri-Service athletic competition.

Personnel changes include LT Robert Moliski relieving LT David Hovda as Junior/Senior Class Advisor and Sail Training Officer, LT Jeffery Reeves relieving LT Michael Quinlan as Sophomore Class Advisor and Supply Corps Chief Petty Officer William Sulzberger relieving Supply Chief Linda Potts.

CAPTAIN ROBERT W. SHERER

Office of the Dean of the Graduate School

Federal Fellows' Tuition Shortfall

A major concern for the ODGS during the past year was the rapidly growing tuition shortfall associated with MIT's participation in the National Science Foundation's graduate fellowship program. This shortfall results from the fact that NSF provides only \$6,000 toward the tuition of each fellow in the form of a cost-of-education allowance, and requires that MIT accept that allowance in lieu of tuition and fees. With MIT's 12-month tuition and hospitalization insurance fee for the 1989-90 academic year at \$20,138, with nearly 200 NSF fellows in residence at MIT, and taking into account the impact of several other small federal fellowship programs with similar shortfalls, the total projected shortfall for the past year was \$2.9 million. This figure impacts directly on the bottom line of the Institute's financial operations and has been a topic of concern for many years. However, the shortfall took on even larger import as we considered the continued growth of tuition and NSF's announced plan to double the number of NSF fellows over the next few years without an attendant commitment to increase the cost-of-education allowance.

In response to this growing concern, the Provost and the Dean of the Graduate School explored with NSF the possibility of an increase in the cost-of-education allowance and moderation of the "in lieu of tuition and fees" requirement. These efforts were unsuccessful. Efforts were also made to effect a change in NSF's rules such that reimbursement for a portion of the shortfall could be obtained by allowing fellows to serve as part-time research assistants with some of the resultant stipend and all of the employee benefit pool scholarship being applied to the fellow's tuition. Dean Perkins negotiated an apparent settlement with the NSF regarding such a rules change; however, this change was subsequently rejected by the National Science Board.

Having failed to reach an equitable agreement with the NSF, MIT unilaterally adopted a change in its own internal procedures so as to limit the growth of the shortfall. Specifically, an upper bound of \$2.9 million was set on the General funds that would be made available in the coming year for meeting the shortfall. Each department was allocated a pro rata share of this amount, based on the departments' most recent enrollment of NSF fellows, and was directed to honor NSF fellowships only to the number that these funds would support or find other unrestricted departmental funds. This procedure was put into effect during the spring term for the 1990-91 academic year. Data available at the end of the current year suggest that the total number of active NSF fellows at MIT in the coming year will be comparable to the past year's numbers and that the number of first year fellows will actually be somewhat less than a year ago. It is too early to determine how much these numbers reflect normal year to year fluctuations and how much change can be attributed to our new policy. However, it is likely that the policy will play an increasingly important role in future years.

Administration of Graduate Support

The single largest activity in the ODGS is the handling of paperwork associated with the administration and processing of graduate awards, assistantships, and petitions. The efficiency and reliability of this activity was improved during the past year due to a number of positive factors including: the presence of a relatively more stable staffing situation than in recent years, increased familiarity with and use of the office computer network, and the adoption of clearer lines of responsibility for each of the major administrative operations. This increased efficiency has become essential as the number of graduate students has grown, as new fellowship programs have come into being (e. g., the National Defense Science and Engineering Grant program and the Hughes Medical Institute Graduate Fellows program in the last two years), as MIT has continued to be a primary school of choice for many fellowship recipients, and as MIT's dependence on research assistantships for a major portion of graduate student support has continued

We commented in last year's report on the large fraction of time spent by the ODGS staff on graduate student counseling of various kinds. The demand for such services continued unabated during the past year despite the availability of many other professional counseling services at the

Institute. The ODGS is happy to be viewed as a place where such services are available and especially helpful.

The ODGS continued to administer a number of activities for which it annually takes major responsibility including:

- the nomination and selection process for a number of competitive industrial and endowed fellowships that are administered by the ODGS,
- the Workshop for Graduate Teaching Assistants which, for the first time this past year, was held jointly with the orientation program for new faculty members,
- administration and allocation of various funds made available for graduate student support through endowment and through the College Work Study Program, and,
- preparation of publications such as the Graduate School Manual and the Practical Planning Guide for newly admitted graduate students.

In addition, the ODGS and the Payroll Office sponsored a well attended workshop on graduate student tax issues.

Minority Support and Outreach

The Minority Summer Science Research Program celebrated its fifth consecutive summer intern program, managed very effectively by Dean Margaret Tyler. Twenty-five student interns from underrepresented groups were selected from a record number of applicants. Of these, nineteen elected to participate, several from schools that had not participated in the past. As with last year's program, more faculty requested summer interns than could be accommodated within the financial constraints of the program. Nevertheless, the program was able to expand into new areas, placing an intern in the National Magnet Laboratory for the first time. This placement has proven to be so successful that the laboratory has invited its intern to stay for an extra two weeks and has arranged for his continuing involvement in a research project throughout academic year 1991. Another intern will be matriculating in the graduate program in Toxicology in the fall term, 1990.

Over the five-year existence of the Minority Summer Science Program, seventy-four students interns have participated. Fifty-six have completed their undergraduate programs; and of these, five have matriculated in M.I.T.'s graduate Chemistry and Toxicology programs and fifty are known to have enrolled in other masters' and doctoral programs or in medical schools.

An initiative was undertaken this past year to secure the long-term financial stability of the Summer Science Program. With the assistance of staff in the Resource Development area, several successful fund raising efforts produced \$150,000 in endowment funds for the program. Efforts will continue towards the target of \$2 million. In addition, generous corporate and foundation support, including the first use of five-year partial funding from the Howard Hughes Medical Institute, continued to provide expendable funds for the program.

Deans Tyler and Colbert presented for underrepresented students several workshops and discussion sessions designed to increased students' knowledge about applying for and funding graduate education. These events drew large numbers of minority students and also served as opportunities for students to meet and talk with faculty and staff members.

The Graduate School Office, in conjunction with the Student Affairs Office and the Office of Minority Education, organized and funded numerous cultural events for students from underrepresented groups. Among these were the second annual observance of Kwanzaa during the first week of December, four events for Black History Month in February, an ongoing series of

minority discussion groups, and two lectures on African history. In addition, the office assisted the Black Graduate Student Association (BGSA) in presenting the fourteenth Ebony Affair dance early in March. Cooperative arrangements with other offices concerned about minority affairs have worked well to maximize resources and provide minority graduate and undergraduate students with an increasingly broad range of cultural and intellectual events

Dean Tyler, with assistance from John Wilson of the Corporate Development Office, raised funds to begin a program designed to assist departments with their minority faculty and graduate student recruitment. The HBCU Visiting Faculty Program is designed to develop an association between select African-American science, engineering and business faculty from historically Black institutions and their counterparts at M.I.T. Faculty visits began in the first program year with a series of short "symposium visits" by HBCU faculty to provide an overview of recent key science and engineering topics, to review M.I.T. resources and to make initial faculty contacts. Two faculty symposium visits occurred during the past year, and there are plans for several additional visits during academic year 1991. For the second year, successful contacts are expected to expand into more substantial one-year residencies as Visiting Research Fellows and to conduct collaborative research. The visiting researchers will be encouraged to invite one or more of their top students to attend symposia. The long-term goal is to attract more African-American applicants to our graduate programs and to generally enhance the presence of minority scholars within the Institute community.

Individual Activities

Individual staff members of the ODGS were active in various Institute and external activities. Dean Perkins represented the Graduate School on an ad hoc Institute Committee that considered changes in the academic calendar in order to relieve end-of-term pressures, especially those resulting from compression of the time available for final exams. This committee was able to make recommendations for modest temporary changes which were subsequently adopted by the faculty. Dean Perkins was also active in the Association of Graduate Schools (AGS) in the Association of American Universities (AAU) where he served as a member of the Executive Committee, and on the Working Group on Federal Graduate Education Policy which prepared an AAU policy statement entitled "The Ph.D. Shortage: The Federal Role"

Dean Colbert continued his activities on behalf of the International Scholarship Committee, advising students about the availability of international study and research opportunities and on application procedures. In the past year, M.I.T. fielded one successful applicant for the British Marshall Scholarship and three successful applicants for the Fulbright Scholar Program. Given a total of nine applicants, the Institute continued to have reasonable success. A priority for the coming year, however, is to find additional means to publicize more widely the availability of these opportunities and interest more M.I.T. students in following through with their applications. Dean Colbert was also active on the Committee on Postdoctoral Issues, which recommended the inclusion of all postdoctoral fellows into the staff health insurance plan and thus improve the health coverage options available to that group. Dean Colbert also served on the Martin Luther King Memorial Celebration Committee, which organized the observance of Dr. King's birthday in January. The committee is currently pursuing plans to bring to M.I.T. a significant African-American scientist for an extended visit and is planning a number of academic activities associated with that event. Also, Dean Colbert has served as the coordinator for data exchange for the graduate deans and associate deans of the Ivy League Plus group (known as the Dwarves and Elves) and has created a number of standard spreadsheets, reporting rules and data transfer procedures that will be used for future information exchanges among these institutions. In addition, Dean Colbert has continued his service as Treasurer and Member of the Board of the Cambridge Partnership for Public Education and has assumed leadership of the Boston Chapter of the Quality Education for Minorities (QEM) Project.

COMMITTEE ON GRADUATE SCHOOL POLICY (CGSP)

The CGSP experienced a relatively quiet year with very few issues coming to the point of formal actions. The committee did spend a considerable amount of time following the NSF tuition shortfall deliberations and did voice considerable concern over the possible consequences of any policy which limits the ability of NSF fellows to pursue their graduate studies at MIT. These concerns were acknowledged by the Dean and the Provost; however, the CGSP was unable to offer viable alternatives for relieving the shortfall problem.

The CGSP heard and debated a proposal to establish a formal mechanism for part-time graduate student status in order to meet family obligations while pursuing a graduate degree program. This proposal was included as one of many recommendations in a report prepared by the Institute's Committee on Faculty and Work. No action was taken by the CGSP; however, it is clear that this is an issue on which formal action will be required in the near future.

The Graduate School's policy regarding "thesis in absentia" was also debated. It was discovered that our formal policy on this topic apparently was omitted from the Graduate School Manual some years ago when the policy for nonresident doctoral dissertation status was adopted. Since the latter does not in any way preempt the former, a degree of ambiguity regarding our thesis in absentia policy was found to exist. The CGSP was clearly in agreement that a level of departmental control over theses done in absentia should exist but did not reach agreement over the degree of formality or of the levels of approval that should be required. These issues are on the agenda for the coming year.

The Registrar brought to our attention the issue of letter grades for subjects taken by MIT graduate students at Harvard University under terms of our cross enrollment agreement. Passing grades in such subjects had been recorded on the MIT transcript as "S" (satisfactory); the Registrar proposed the assignment of MIT-equivalent letter grades wherever such equivalencies could reasonably be established. After considerable debate about the appropriateness of certain equivalencies, the proposal was approved by the CGSP.

The Admissions Office proposed changes in procedures for admitting and registering special graduate students. The proposal would allow the admission decision and registration procedure to be implemented simultaneously through the Admissions Office thereby simplifying and speeding up the processing of special student registrations. The CGSP endorsed the proposal and in the process reaffirmed the policy governing tuition charges for special students who drop subjects part way through the term.

The CGSP approved proposed changes to the Nuclear Engineering Department program in Radiological Sciences.

The CGSP conducted its regular end-of-term reviews of academic performance and recommending of graduate degrees. During the past year the CGSP continued to emphasize use of the "U" grade for unsatisfactory thesis progress and put special emphasis on issuing departmental or dean's warnings to students whose registration for thesis has extended beyond reasonable limits. This action was taken in part as a response to national and internal concerns over increasing time to degree completion in many fields.

I and my colleagues in the ODGS wish to express our thanks and appreciation to the 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: Charles Counselman III (EAPS) replaced by Frederick Frey, Drew Fudenberg (Economics) replaced by William Wheaton, and Craig Dorman (WHOI) replaced by John W. Farrington.

GRADUATE SCHOOL STATISTICS

Important statistics concerning the Graduate School are presented in Tables I-IV, which follow. The enrollment data in Table I reflect a small (68 students or 1.4%) increase in total enrollment from the previous year. This increase is accounted for almost completely by an increase of 67 students in the School of Management leaving the graduate enrollment figures for the rest of MIT essentially unchanged. As has been true for several years now, the enrollment of women remained nearly stable at 20% of the total graduate population. The failure of this figure to grow continues to be a source of concern. Of even greater concern, however, is the small enrollment of underrepresented minorities, and the decline in both absolute numbers and percentage of the total which is evident in their enrollment figures. While these figures are consistent with the experiences reported nationally at many other institutions, we must express great disappointment at the apparent failure to date of national and local recruiting efforts to bring about enrollment increases. On a more hopeful note, the Department of Chemistry, with input from the Biology and Chemical Engineering Departments, has begun a long-term effort to increase the number of African-Americans participating in the chemical sciences. While the effort has not yet produced an upturn in the number of minority admissions or in the number of undergraduate minority chemical sciences majors, we are optimistic that the initiatives proposed by those departments will have longitudinal effects.

The graduate student financial data in Table II are consistent with similar data from recent years. In particular, these data continue to demonstrate our dependence on research assistantships and the research funding that makes such assistantships possible. The tuition support figures represent an increase of 6.6% which is somewhat less than that which would have been expected in light of MIT's general tuition increase and enrollment. However, stipend support increased by 8.7% which is somewhat larger than can be explained by MIT's formal stipend increases and enrollment figures. Some of that increase may be accounted for by departmental stipend adjustments which were made in response to a change in Massachusetts state income tax law. That change, which was described in last year's report, caused many stipends to become subject retroactively to state income tax for all of the 1989 calendar year.

The figures in Tables III and IV show no significant changes, at least with respect to totals for the entire Graduate School, from those of the previous year, and are indicative of its currently stable size and scope.

FRANK E. PERKINS

	<u>FOREIGN</u>	<u>WOMEN</u>	<u>MINORITY</u>	<u>NEW</u>	<u>NON-RESIDENT</u>	<u>TOTAL</u>
SCHOOL OF ARCH & PLANNING						
Architecture	70	79	9	93	17	267
Urban Studies & Planning	46	74	22	66	28	181
SCHOOL OF ENGINEERING						
Aeronautics & Astronautics	70	19	6	62	2	214
Chemical Engineering	86	34	6	47	7	219
Civil Engineering	142	47	7	83	10	263
Elec Eng & Computer Sciences	145	110	20	150	0	674
Materials Science & Engineering	82	52	6	38	3	186
Mechanical Engineering	142	53	11	99	3	402
Nuclear Engineering	64	14	7	27	0	149
Ocean Engineering	55	12	1	44	0	144
SCHOOL OF HUMANITIES & SOC SCIENCE						
Economics	43	30	5	36	9	138
Linguistics & Philosophy	37	22	0	11	5	71
Political Science	44	46	3	34	38	162
Science, Technology & Society	1	3	0	4	0	9
SCHOOL OF MANAGEMENT						
	237	125	17	331	11	635
SCHOOL OF SCIENCE						
Applied Biological Sciences	9	13	0	0	1	30
Biology	25	79	1	36	0	194
Chemistry	49	74	6	64	4	262
Earth, Atmosph & Planetary Sci	50	44	3	36	1	174
Mathematics	60	17	1	21	9	118
Physics	106	28	13	48	2	303
Toxicology	7	11	2	6	0	22
WHITAKER COLLEGE						
Brain & Cognitive	10	9	1	12	0	50
Health policy & Management	0	0	0	0	0	2
HEALTH SCIENCES & TECHNOLOGY						
	4	5	1	0	1	21
TOTAL GRADUATE ENROLLMENT						
	1584	1000	148	1348	151	4890
CATEGORY AS % OF TOTAL						
	32%	20%	3%	28%	3%	

"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 1989

CATEGORY OF SUPPORT	NO. OF STUDENTS (ACTUAL)	NO. OF STUDENTS (EFS)	TUITION FALL TERM	TUITION SPRING TERM	STIPEND FALL TERM	STIPEND SPRING TERM	TOTAL ACADEMIC YEAR SUPPORT
RESEARCH ASSISTANTSHIPS	2660	1,977	\$14,335	\$14,069	\$9,191	\$9,042	\$46,637
TEACHING ASSISTANTSHIPS	757	474	\$3,435	\$3,235	\$2,274	\$2,181	\$11,125
GRADUATE INSTRUCTORSHIPS	10	5	\$34	\$30	\$159	\$98	\$320
FEDERAL FELLOWSHIPS/TRAINEESHIPS	340	197	\$1,425	\$1,353	\$1,458	\$1,436	\$5,671
MIT ENDOWED SUPPORT (DEPTL)	171	90	\$652	\$656	\$375	\$323	\$2,006
MIT ENDOWED SUPPORT (ODGS)	59	47	\$342	\$313	\$97	\$81	\$833
MIT GENERAL SUPPORT	632	424	\$3,080	\$3,012	\$1,041	\$1,059	\$8,192
INDUSTRIAL FELLOWSHIPS	198	92	\$669	\$709	\$820	\$817	\$3,014
FOUNDATION FELLOWSHIPS	237	170	\$1,230	\$1,234	\$509	\$508	\$3,481
BILLED TO MIT BY OUTSIDE SPONSORS	362	273	\$1,982	\$1,635			\$3,617
TOTAL IDENTIFIED SUPPORT	5426	3,749	\$27,184	\$26,245	\$15,922	\$15,545	\$84,896

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 THE FALL TERM TUITION OF \$7250 PER STUDENT.

TABLE II: SOURCES AND AMOUNTS OF GRADUATE STUDENT SUPPORT, 1989-1990 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 ARCH & PLANNING	954	276	0.29	164	0.59
Architecture	608	150	0.25	97	0.65
Urban Studies & Planning	257	126	0.49	67	0.53
Real Estate Development*	89				
SCHOOL OF ENGINEERING	3406	948	0.28	477	0.50
Aeronautics & Astronautics	289	130	0.45	61	0.47
Chemical Engineering	250	87	0.35	49	0.56
Civil Engineering	333	168	0.50	79	0.47
Elec Eng & Computer Sciences	1590	209	0.13	104	0.50
Materials Science & Engineering	236	69	0.29	36	0.52
Mechanical Engineering	506	181	0.36	93	0.51
Nuclear Engineering	66	44	0.67	26	0.59
Ocean Engineering	88	60	0.68	29	0.48
Technology & Policy*	46				
Transportation Studies*	2				
SCHOOL OF HUMANITIES & SOC SCIENCE	745	192	0.26	82	0.43
Economics	366	66	0.18	34	0.52
Linguistics & Philosophy	137	28	0.20	11	0.39
Political Science	212	90	0.42	33	0.37
Science, Technology & Society	30	8	0.27	4	0.50
SCHOOL OF MANAGEMENT	1816	422	0.23	220	0.52
Sloan School	1766				
Operations Research*	50				
SCHOOL OF SCIENCE	1727	495	0.29	193	0.39
Biology	417	72	0.17	35	0.49
Chemistry	326	140	0.43	61	0.44
Earth, Atmosph & Planetary Sci	131	52	0.40	32	0.62
Mathematics	241	59	0.24	21	0.36
Physics	612	172	0.28	44	0.26
WHITAKER COLLEGE	195	31	0.16	17	0.55
Brain & Cognitive	172	21	0.12	12	0.57
Toxicology	23	10	0.43	5	0.50
HEALTH SCIENCES & TECHNOLOGY	12	0	0.00	0	0.00
INSTITUTE TOTALS	8855	2364	0.27	1153	0.49

*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 1989

	NUMBER OF INDICATED DEGREES				
	Ph.D	Sc.D.	ENGINEERS	MASTERS	TOTAL
SCHOOL OF ARCH & PLANNING					
Architecture	4			90	94
Urban Studies & Planning	12			66	78
SCHOOL OF ENGINEERING					
Aeronautics & Astronautics	9	2		67	78
Chemical Engineering	35	7		38	80
Civil Engineering	27	5	1	62	95
Elec Eng & Computer Sciences	68	4	12	130	214
Materials Science & Engineering	31	7		19	57
Mechanical Engineering	29	5	2	129	165
Nuclear Engineering	17	2	5	27	51
Ocean Engineering	9		13	37	59
SCHOOL OF HUMANITIES & SOC SCIENCE					
Economics	22				22
Linguistics & Philosophy	14			4	18
Political Science	14			19	33
Science, Technology & Society					
SCHOOL OF MANAGEMENT					
	16			309	325
SCHOOL OF SCIENCE					
Applied Biological Sciences	6			4	10
Biology	22			3	25
Chemistry	46			5	51
Earth, Atmosph & Planetary Sci	26	2		16	44
Mathematics	18			5	23
Physics	32	1	4	47	84
Toxicology	2				2
WHITAKER COLLEGE					
Brain & Cognitive	9			2	11
Health policy & Management	3			3	6
HEALTH SCIENCES & TECHNOLOGY					
	5			1	6
TOTAL GRADUATE DEGREES	476	35	37	1083	1631

THESE FIGURES INCLUDE 32 DEGREES AWARDED THROUGH MIT-WOODS HOLE OCEANOGRAPHIC INSTITUTION JOINT PROGRAM AS FOLLOWS.
15 Ph.D's(4 in Engineering, 11 in Science), 3 Engineer's and 14 Master's Degrees(9 in Engineering, 5 in Science)

TABLE IV: GRADUATE DEGREES AWARDED IN ACADEMIC YEAR 1989-1990

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 1989-90, LIS offered 39 different courses. The fields of instruction included analog and digital electronics including microprocessors through advanced applications, electronic imaging and machine vision, computer literacy, computer programming in BASIC and C, mechanical drafting, geometric dimensioning and tolerancing, computer aided drafting and circuit board design, alarm technology, scientific glassblowing, 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 and computer aided drafting. Computer applications on the IBM PC, including Lotus 1-2-3 and WordPerfect, were added, as well as courses covering the PC disk operating system. Some courses were also offered during the day to accommodate the demand.

The Alumni Association of LIS contributed \$7,500 to purchase a hardware system to greatly improve instruction in the computer classroom. This device permits the instructor to monitor, conduct demonstrations and even take control of each student's computer without leaving the instructor position.

Lack of interest in the mechanical drafting program dictated that no new applicants were accepted for the *Certificate in Drafting Technology*. Those currently enrolled will be permitted to complete the program.

AFFIRMATIVE ACTION

LIS admitted a total of 900 students to its courses in 1989-90. Of those enrolled, 78 percent successfully fulfilled the certificate requirements. Among those who completed courses were 97 MIT employees, an increase of 64 percent over last year. Fourteen students earned the *Certificate in Electronics Technology*, and seven students earned the *Certificate in Drafting Technology*. Twenty percent of the students were women who desire to enter or improve their positions in technical fields. The instructing staff of 37 includes nine 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

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 are as follows:

Summer 1988 - 2146 registrations in 68 special programs by 2096 individuals

Summer 1989 - 1800 registrations in 72 special programs by 1750 individuals

Foreign citizens comprise approximately 12 percent of this registration.

Regular Students

Graduate students comprise 86 percent of the student body in summer. The 1989 registration of 3,146 students was an increase from 3,137 in 1988.

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-third 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 college placement of graduates and 70 percent retention of participants) over much of its twenty-three 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 student 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 p.m. and Tuesday and Wednesday from 3:00 to 8:00 p.m. 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 1990

Ninety percent of the Program's graduating seniors have enrolled in the following institutions: Carnegie Mellon University, Emmanuel College, Fitchburg State College, Johnson C. Smith University, Massachusetts College of Art, Salem State College, Tuskegee University, and Wheelock College.

RONALD S. CRICHLAW

MIT/ WHOI Joint Program in Oceanography and Oceanographic Engineering

Effective November 15, 1989, Ronni Schwartz replaced Mary Athanis as the Administrator of the Joint Program with the Woods Hole Oceanographic Institution (WHOI).

On November 13-14, 1989, the Oceanography section of the Navy reviewed the MIT/WHOI Joint Program in Oceanography/Oceanographic Engineering. The purpose of the visit was to assess the effectiveness of naval participation in the Joint Program and to consider several proposed changes in the curriculum. The participants included the Oceanographer of the Navy, Admiral Richard M. Pittenger; his staff, including Mr. R.S. Winokur, Commander W.T. Sleichter, and Dr. C.A. Collins who is the current Chairman of the Naval Postgraduate School in Monterey, CA; MIT Professors Sallie W. Chisholm, Arthur B. Baggeroer, Carl I. Wunsch, and W. Kendall Melville; and WHOI personnel including Dr. Craig Dorman, Professors Dana Yoerger, and Elazar Uchupi; and Mr. A.L. Peirson, Associate Dean for Education at WHOI.

Two significant changes were proposed: (1) that the program in Physical Oceanography is designed for Doctoral students, and therefore the entry-level Master's degree program in Physical Oceanography should be discontinued except in extraordinary cases; and (2) that exceptional naval officers should be provided the opportunity to attend the proposed Doctoral Program in Physical Oceanography. Admiral Pittenger further stated that it was his desire to encourage greater participation of naval officers in the Joint Program by making the opportunity available to a wider range of naval personnel.

Enrollment in the Joint Program increased 28 percent - from 98 in 1988-89 to a level of 125 in 1989-90. The projected enrollment estimate for September, 1990 is 140 students, with 15 in Chemical Oceanography, 21 in Marine Geology and Geophysics, 23 in Biological Oceanography, 42 in Oceanographic Engineering, and 39 in Physical Oceanography.

There were 135 applicants to the Joint Program for 1990-91, a figure slightly higher than that of last year. Forty-seven students were admitted to the program; of these, 27 (57%) accepted our offer of admission. Women comprise 30 percent of the entering class. Of the incoming students, all but seven will be doctoral students.

Overall, the Joint Program graduated 16 students in 1989-90; of these, 12 received the doctorate, two received the Master's degree, and two received the Engineer's degree. The breakdown by discipline is as follows: Chemical Oceanography (three); Biological Oceanography (three); Marine Geology and Geophysics (six); Physical Oceanography (zero); and Oceanographic Engineering (four).

Dr. Craig Dorman, Director of WHOI, continued in the position of Acting Dean for Graduate Students at WHOI. Effective August, 1990, Dr. John W. Farrington will assume the dual role of Associate Director for Education and Dean of Graduate Students at Woods Hole. 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.

In June 1990, The Wood's Hole Oceanographic Institution celebrated its 60th anniversary. In conjunction with this event, the commencement exercises held at Woods Hole not only conferred degrees on the 1989-90 graduates but also recognized the 177 alumni who have graduated since June 1980.

SALLIE W. CHISHOLM
RONNI SCHWARTZ

Office of the Dean for Student Affairs

INTRODUCTION

Through the excellent teamwork of a group of very dedicated staff, the Office of the Dean for Student Affairs (ODSA) was able to do the seemingly impossible again this year: it absorbed a significant increase in student use of the Office's various services and programs; it successfully managed a new academic support program and a recently established public service center; it handled an increased discipline and harassment caseload; it provided support to, or served on, a growing number of *ad hoc* or standing faculty and Institute Committees; it attracted a record number of faculty as leaders of seminars, as freshman advisors, and as House Fellows; it significantly increased productivity as a result of its computerized local area network; and it kept on top of an unexpected deluge of calls, letters, and other special requests growing out of the public's response to the report of a national project conducted under the Office's auspices. Dedication, hard work, mutual support, and very little turnover in staff all made for a most exciting and productive year.

In the pages that follow, we have tried as in previous years to capture the essence of this year's activities while keeping in mind the importance of providing basic data that may be of use in longitudinal Institute studies.

Public Service Center

The MIT Public Service Center has just completed its first full academic year; it has been a successful year which included a move in October from the Student Center to the Infinite Corridor. Our main goal for 1989-90 was "exposure."

The Center sponsored two large projects in the fall: (1) Public Service Day on October 14, and (2) "The Giving Tree" in December. Twenty-three agencies and over 350 students participated on Public Service Day. "The Giving Tree" at Christmas was conceived the previous year by students at 500 Memorial Drive as an in-house project. Representatives from that dormitory approached the Public Service Center to make it campus-wide. As a result, trees in three dormitories, Alpha Phi's meeting room, in offices on campus, and in the student center benefitted 13 agencies and 717 children.

Other first-semester activities included responding to more than 300 tear-cards about public service which had been in the centerfold of the Freshman Handbook and to an additional 90 interest forms completed by freshmen at the Activities Midway. Because Rachel and Her Children, a book on homelessness in America, had been sent to all freshmen, the Center became a part of "explorations" on Friday of R/O week by offering students the opportunity to work in one of six shelters. The Center was also asked to create a Public Service Center "bookmark" for the "Scientific Illiteracy" Colloquium, mainly to advertise ways to get involved with tutoring. A bi-weekly Volunteer Opportunities Tech column was started, the IAP credit-bearing seminar "American Miseries" was organized, and the Center was featured in the lead article for the Fall '89 Spectrum (the publication of MIT's Campaign for the Future). From that feature, funds were received to create and help endow the Priscilla King Gray Public Service Fund for student fellowships.

January was equally as fulfilling. Good first-of-the-year news was that the Center had received a \$25,000 grant from the Boston Foundation. Part of the award was used to support three \$1,000 Spring '90 fellowships to students taking the IAP seminar for credit so that they could continue their January initiated field service.

The Center's pace did not let up in the spring. The IAP seminar won the COOL (Campus Outreach Opportunities League) award for Outstanding Faculty Participation; honorable mentions were received for exemplary projects by ARMIT for its World AIDS Day project, and by Rosina Samadani and Ajay Advani for their seminar Homelessness And You. Other Center related activities included the awarding of five \$4,000 summer '90 fellowships, the production of two newsletters, and a clothing drive at McCormick Hall to benefit Rosie's Place.

The Quality Education for Minorities (QEM) Project

The highlight of the year for the QEM Project was the release on January 9 of its report: "Education That Works: An Action Plan for the Education of Minorities." This report was prepared following a series of regional meetings involving hundreds of educators, parents, students, and community leaders in which participants identified barriers to, as well as effective strategies for, quality education and academic achievement by minority and low-income students. The public's response to the report has been steady and substantial, with considerable enthusiasm shown for the holistic approach (that is, spanning the entire formal educational cycle) reflected in the report's recommendations and for the call for collaboration and coordination of efforts at the national level. Following three very productive years at MIT, the QEM Project officially terminated on June 30 of this year. It will be succeeded at the national level by the Washington-based, non-profit organization QEM Network. Several of MIT's faculty, staff, and students contributed to the success of this project and we are very grateful to them. We thank each of them on behalf of the many children we hope will benefit in the future from this project and its successor organization.

Other Major Developments

The International Issues Group sent a final report to the Provost listing recommendations that it felt the Institute should follow as a consequence of the major study and review the Group conducted of support services provided to international students and visitors. In addition, the Minority Student Issues Group's third and final report, to focus on the recruitment and retention of minority faculty at MIT, will be an internal MIT document, based upon the advice of Professors Kenneth Manning and Arthur Smith under whose leadership the report is being prepared. The report, expected to be available this fall, will be initially submitted to the President and Provost, the Equal Opportunity Committee, and the Faculty Policy Committee. Ultimately, the report is expected to be presented to the general faculty.

Within the ODSA, the staff have continued to develop their computer expertise, due to the diligent effort and support of Steven Burke, Assistant to the Dean. Currently, 35 members of the staff are directly connected to the Office's Macintosh local network, with 5 others running Local Talk in the Student Center. Forty-one members of the staff have access to E-Mail which has considerably increased communication with students and with other staff, both within and outside of the ODSA. Administrative and Support Staff have praised the changes and an increase in productivity across the various sections has been very evident.

Affirmative Action Successes and Objectives

The ODSA continued to maintain a strong commitment to Affirmative Action during the year, with a staff that was 20% minority and 27% male. The following table reflects the race/ethnicity and gender profile, as of June 30, 1990 of the 45 full- and part-time positions in the ODSA:

	Minorities	Non-Minorities	Total
Administrative & Academic Staff			
Male	2	9	11
Female	5	16	21
Subtotal	7	25	32
Support Staff			
Male	0	1	1
Female	2	10	12
Subtotal	2	11	13
TOTAL	9	36	45

The 2 minority men in the administrative and academic staff category include 1 Black American and 1 Puerto Rican. The 5 minority women in this category are Black. Not included in these numbers is the Dean-on-call who is a Black male or the Staff of the Quality Education for Minorities Project which until January when the Project's final report was released included 1 Black male and 3 Black females. Of the 2 minority females among the 13 support staff members, 1 is Black and 1 is Asian.

During Fiscal Year 1990, minorities and males together represented 67% (3 minority and 1 male) of the new full and part-time persons hired and 50% (2 minority) of the promotions within the department. The hiring of at least 1 Asian American to the full-time Administrative Staff remains as a goal for Fiscal Year 1991.

We are very proud of our accomplishments in the area of Affirmative Action; we continue to find great strength and energy in the racially and ethnically diverse group of men and women who make up the ODSA staff.

On a personal note, this year represents the end of a ten-year tenure for me at the Institute. As of July 1, I will assume the position of President of the Washington-based successor organization to the QEM Project (the Quality Education for Minorities Network) with two years of support from MIT. In reflecting on the last ten years, I know that I have benefited enormously from the opportunity to work and learn in this environment; that experience was made special by the extraordinarily talented men and women who make up MIT's faculty, staff, and student body. As Dean, my initial focus was within the ODSA, trying to bring its staff and programs to a level at which the staff could feel good about our efforts and at which faculty and students would feel confident in seeking our assistance. Throughout my tenure, my inclinations and efforts have weighed heavily in the direction of trying to make MIT a more hospitable and supportive place for women and minority male students who, historically, have been underrepresented in the student body here; to help instill confidence again in previously successful students about their abilities to achieve in this environment; to increase the number of opportunities for students, especially freshmen, to interact informally and regularly with members of the faculty; and to provide a mechanism through which students could volunteer their time in service of others. Thanks to the work and

support of many individuals from around the Institute, I believe that MIT has improved and will continue to do so as it continues to respond in the coming decade to the needs of an increasingly diverse student body.

SHIRLEY M. MCBAY

Central
MARILYN BODNAR
STEVEN BURKE
ALBERTA LIPSON
VIRGINIA SORENSON
BETTY SULTAN

QEM Project
RICHARD HOPE
PAUL GOODWIN
RENE SMITH-MADDOX
KEVA WRIGHT

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 Faculty Committee on Academic Performance (CAP), Undergraduate Seminars, the January Independent Activities Period (IAP), the Wellesley-MIT Exchange Program, and the Institute Colloquium.

1989-90 was a year marked by solid UAS achievement, particularly in the areas of freshman advising, IAP, Residence/Orientation, and Undergraduate Seminars. It has also been a time of extraordinary harmony and an enhanced spirit of genuine collaboration among the office's staff and support staff.

The year's activity in each of the major UAS programs is summarized below.

Freshman Advising Program

There were 227 freshman advisors during 1989-90, including: 117 faculty; 5 instructors/lecturers; 8 research staff members; 13 graduate students; and 61 administrators. Some 218 undergraduates worked with these advisors as associate advisors.

Our efforts to stimulate more intensive advising have continued this year. Almost all advisors worked with a group of at least three-to-five students, and many took on as many as ten. As before, we encouraged the advisors to meet on a bi-monthly basis with their groups, offering the usual modest financial support for social and other exchanges. Twice-yearly advisor orientations were carried out. Associate advisors also received an orientation session, and met as a group on several occasions throughout the year to discuss their roles and responsibilities. These programs will be expanded during the next academic year to include information sessions on various Institute programs and offices.

We kept advisors and freshmen informed of important news through a series of postcard announcements; many advisors have appreciated the efficiency of these shortened messages. The Freshman Watch continues to expand. Thanks to swift cooperation from core departments, we are generally able to alert advisors to potential dangers sooner than most Performance Evaluations can. We are running a pilot study of the Evaluations to assess the need for their continued existence.

Three freshmen withdrew for a variety of personal reasons during the academic year. Eleven additional freshmen were required to withdraw for at least one term because of unsatisfactory academic performance. The table below summarizes CAP actions over the past five years regarding unsatisfactory academic performance, as well as the number of the more informal UAS letters suggesting that the student review his or her performance.

Academic Year	Required Withdrawals	CAP Warnings	UAS Letters	Total Academic Actions
1989-90	11	91	101	203
1988-89	14	107	82	203
1987-88	10	91	91	192
1986-87	8	91	84	183
1985-86	10	94	73	177

Residence/Orientation (R/O)

The first taste of MIT for many undergraduates is the annual Residence/Orientation Week starting in late August. The program, which actually lasts 12 days, is coordinated by upperclass students, in collaboration with UAS and other ODSA staff. This year's R/O was organized by Elizabeth M. Ling, '89, Christine K. Rosenwasser, '90, and Andrew R. Parsons, '91.

R/O '89 built on the success of innovative programming during R/O '88, which sought to draw a clear line between the residence selection and academic orientation components of R/O. New students were introduced to the academic aspect of orientation at a lively mixed-media Convocation in Kresge. Postponing the initial advisor/advisee contact to a picnic right after the Convocation resulted in unusually high faculty turnout.

Rachel and Her Children, Jonathan Kozol's depiction of homelessness in New York City, which was mailed over the summer to the entire entering class, provided the impetus for the 1989 Book Night Presentation in Kresge. Attended by a majority of the Class of 1993, the presentation was followed, as in the past, by dinner with members of the MIT faculty and administration in a total of 43 MIT living groups. This year, the Freshman Book was directly linked to a Public Service Center initiative, involving tours of local shelters and kitchens. As a result of this collaboration, a number of new students became active in volunteer work in the Boston area. The theme was again taken up in a seminar during IAP as well as in several activities encouraging students to volunteer in shelters for the homeless.

Administrative Support to the Committee on Academic Performance (CAP)

The CAP was chaired this year by Professor Preetinder Virk. During the year, the Committee handled approximately 450 petitions from individual students requesting readmission and exceptions to certain regulations of the faculty. A total of 70 Required Withdrawals (representing about 1.6 percent of all undergraduates) and 302 Warnings (approximately 7.0 percent) were voted for the academic year, distributed by class as follows.

Class of	Required Withdrawals	CAP Warnings
1990	9	48
1991	20	62
1992	30	101
1993	11	91
TOTAL	70	302

Freshman Advisor Seminars

The Freshman Advisor Seminar program continues to spearhead our drive for more contact-intensive and intellectually-linked advising. This past Fall there were 53 Freshman Advisor Seminars, accommodating 420 of the 850 freshmen who applied for them; 23 of the Institute's 28 academic departments were represented. For Fall 1990 there will be a record 67 Freshman Advisor Seminars, representing 21 of the 28 departments. This array will probably still fall short of meeting the demand for Freshman Advisor Seminars in full, but it gives us a strong foundation on which to build for next year's recruitment of faculty.

Residence-Based Freshman Advising

This year three dormitories (Baker House, 500 Memorial Drive, and New House) and one independent living group (Sigma Alpha Epsilon) had residence-based freshman advising. Baker House had 8 advisors, 38 associate advisors and 40 freshmen, while, respectively, New House had 6, 12, and 25, and 500 Memorial Drive had 7, 17, and 33. SAE was the first independent living group to experiment with this program. Professor Ed Crawley, who is also the House Fellow at SAE, had 1 associate advisor for 3 freshman advisees.

For the coming year, the residence-based freshman advising program has been expanded to include two more dormitories (Bexley Hall and McCormick Hall) and two additional independent living groups (Lambda Chi Alpha and Alpha Delta Phi), making a total of 8 houses.

Bexley Hall will be trying a specially augmented version of residence-based freshman advising. The Housemaster, Professor William Orme-Johnson, assisted by a substantial contingent of associate advisors, will provide academic advising to all the freshmen who are assigned to Bexley Hall. In addition, weekly discussion sessions will focus on areas of shared concern, and student tutors will be hired to provide individual in-house tutoring to those freshmen who want or need it.

Peer Counseling

This past Fall the Big Sister/Little Sister program at McCormick Hall continued to thrive, with 40 upperclasswomen serving as "Big Sisters" to 63 first-year "Little Sisters." The continuing goal for 1990-91 is to have each freshman in the dormitory assigned to a Big Sister, whether or not they are participating in the Residence-Based Freshman Advising program. Another student-initiated program, the Junior Advisor Program in East Campus, was dormant this year, but there are plans to revitalize what has been in the past a successful program. Both programs have as their goals the improvement of community morale and sense of belonging for all students in the house, especially freshmen.

The Undergraduate Seminar Program

There were 49 Undergraduate Seminars for fall term, including 22 "hybrid" seminars admitting both freshman advisees and other students, and 45 seminars in the Spring for a combined total of 94 for both semesters (up from last year's 89), with total undergraduate registration of about 1300 students (up from 1015). This Spring there were also 5 House Seminars, each hosted by an independent living group.

The MIT Colloquium

The two colloquia this year were geared not only to general education of the MIT community on the particular topic, but also to encourage public service participation, especially by students. In October, "Science Smarts: The Scandal of Scientific Illiteracy" focused on the issues of scientific and mathematical illiteracy and the dangerous economic and social consequences of this for the nation. Students were encouraged to find ways to use their own "science smarts" in socially useful ways during their undergraduate years, for example, by tutoring in the local school systems. President Paul E. Gray, Dr. James Rutherford of the American Association for the Advancement of Science, and Ms. Sandra Spooner, Assistant Superintendent of Schools in Cambridge, spoke to a large crowd in Kresge Auditorium. The April Colloquium, entitled "Green: a Colloquium on the Planet," and timed to coincide with the twentieth observance of Earth Day, addressed some of the pressing environmental issues facing us. Mr. Ted Flanigan, of the Rocky Mountain Institute, and Mr. Bill McKibben, noted author of *The End of Nature* and many articles on environmental subjects, were the guest speakers. Each of these events was followed by dinner/discussions hosted by nearly 30 living groups, involving more than 100 faculty and staff.

Independent Activities Period (IAP)

Working closely with the IAP Policy Committee, the UAS staff was involved in completing and evaluating the second year of a two-year experiment designed to strengthen IAP. The experiment was undertaken as a result of concerns that the faculty has not been devoting sufficient energy to creating meaningful educational experiences during IAP and that, therefore, undergraduates have not been reaping educational benefits but have looked on IAP somewhat too exclusively as a time of rest and recreation. The experiment, which was approved by the Committee on the Undergraduate Program, had three objectives: 1) increasing student involvement, particularly by freshmen; 2) increasing the number of credit-bearing activities; and 3) developing internship and public service programs.

To increase student awareness of IAP, the UAS staff expanded information on IAP in the Freshman Handbook and published an IAP Preview in early October. Both publications contained listings of specific sustained activities planned for the following January. The IAP '90 Preview alerted students to 63 activities, nearly half of them for credit. In asking for material for the Handbook and the Preview, the UAS urged departments and faculty to plan their offerings earlier and to include credit subjects in their programs. As a result, during the two-year experiment the number of Guide activities offering credit increased from 28 in IAP '88 to 43 in IAP '89 to 51 in IAP '90. During the same period, the number of undergraduate grades awarded for IAP nearly tripled from 283 in 1988 to 393 in 1989 to 752 in 1990.

The UAS worked with the Public Service Center to develop an Undergraduate Seminar entitled "American Miseries," in which participants were required to do several hours of public service each week. Fifteen students earned credit for the seminar which won a national award.

Data show that the two-year experiment has affected student participation in IAP positively. Not only has the number of students earning credit tripled, but students are spending a larger proportion of IAP on campus. In 1990 half of the freshmen and more than 40% of all undergraduates surveyed said they were at MIT for 100% of IAP. By contrast, in a 1983 survey, only 16% of the freshmen and 19% of all undergraduates said they were at MIT for all of IAP. The percentage of undergraduates reporting that they participated in Guide activities has also increased from 13% in 1983 to 31% in 1990.

While students are on campus more and participating in more activities, faculty involvement in IAP has not improved. Only 23% of the 561 Guide activities were faculty-led. And only about one-fourth of the faculty were involved in Guide activities as participants at any level beyond being a member of the audience. These proportions have remained relatively constant for more than a decade.

Similarly, despite efforts to increase the number of sustained activities, more than half of the activities still met only once and only one-fourth met four times or more.

In May, the IAP Policy Committee, chaired by Professor James Mar, sent a letter to President Gray summarizing its conclusions and recommendations regarding IAP as follows: 1) IAP is a viable enterprise which should add a unique dimension to the education of undergraduates; 2) students have responded positively to credit-bearing offerings; 3) faculty participation is not sufficient for the educational purposes of undergraduate students; and 4) administrative procedures should assign direct responsibility to departments and their faculty for IAP. Currently, the people who organize IAP --- the Policy Committee, departmental coordinators, and the UAS staff--have no real power. The Policy Committee, therefore, recommends: 1) Deans, department heads, and faculty assume line responsibility for IAP with the same devotion and administrative actions as for fall and spring terms; 2) creation of credit-bearing subjects will be the responsibility of every department head and faculty, and each department head shall enjoin her/his faculty to create teaching and learning formats appropriate for IAP; 3) credit-bearing subjects shall be listed in the MIT Bulletin and the Registrar's fall schedule book; 4) the Policy Committee will primarily address issues of policy; and 5) the Policy Committee will continue to work with the UAS in matters such as preparation of the Guide and calendar, and facilitation and coordination of student and staff offerings.

The CUP approved continuation of the IAP experiment for two or three years while the Faculty Policy Committee takes up the issue of possible revision of the academic calendar.

The UAS staff has greatly appreciated the work of Professor Mar in this effort to strengthen IAP.

The Wellesley-MIT Exchange

The Wellesley-MIT Exchange Program continues to offer students of both institutions significant educational opportunities beyond their respective programs despite fluctuations in cross-registration enrollments.

In 1989-1990, 170 MIT students registered for 200 Wellesley subjects as compared with 206 MIT students in 253 Wellesley subjects in 1988-1989. Of these, Religion and Education classes constituted 49% of the subjects taken by MIT students in 1989-1990, while in 1988-1989 these two subject areas comprised only 40% of the number of Wellesley subjects taken. Most MIT students cross-register for the Wellesley subjects taught at MIT, which are in Religion, Education, and Art. Education 102 was offered at MIT in response to growing interest among MIT students to earn teaching certification. Approximately 15 MIT students are currently working toward teaching certification through Wellesley and two MIT graduates will complete their certification in the coming year through a fifth year program at Wellesley. The residence exchange remains a modest program with three MIT students and four Wellesley students participating.

In an effort to increase MIT students' awareness of Wellesley subjects, the Office prepared a booklet in the spring which was distributed with registration materials and mailed to all sophomores.

In his last year as MIT Chair of the Wellesley-MIT Joint Committee, Professor Robert Jaffe provided valuable input in negotiations regarding cooperation between the two institutions, particularly in addressing the program's publicity and the administration and funding of the Exchange bus.

Academic Support and Information Center

The Center, located in 7-104, continues to provide general advice and various informative printed material -- focused particularly on academic opportunities within all of MIT's fields of study -- to increasingly larger numbers of undergraduates.

Career and Course Orientation

Attendance at departmental open houses, coordinated by this office, dropped off in several departments. In the coming year we will reevaluate the efficacy of such open houses and work with departments to strengthen the ways in which departments present themselves to potential majors.

The fourth annual Freshman/Faculty/Alumni Banquet proved a resounding success, providing a good opportunity for students to discuss careers with both faculty and alumni.

Study Skills and Academic Counseling

Study Skills Sessions were offered twice monthly throughout the Fall and Spring. Attendance at these sessions -- especially in the Fall Semester -- increased considerably, averaging 20-25 per session. Extensive individual academic counseling was also carried out.

Staff

There were no changes in UAS staff during 1989-90, resulting in increased stability and momentum as well as continuity within the office.

TRAVIS MERRITT
MARY ENTERLINE
DONNA FRIEDMAN
ALICE LAPIERRE

JEFFREY MELDMAN
STEPHEN PATTERSON
MOYA VERZHBINSKY
BONNIE WALTERS

STUDENT ASSISTANCE SERVICES

Each year Student Assistance Services (SAS) confronts new issues in student services. This past year the concerns of Chinese students were in the forefront as were renewed concerns about harassment. Both issues were constant sources of concern over the course of the year and at year's end remained concerns. Governmental response to pressure from Chinese students has helped clarify the boundaries of the problems for students, but the issue will continue to be real. The Institute has responded officially and thoughtfully to harassment and a report due shortly speaks to the issue. In both of these areas SAS will continue to deal with the individuals affected.

Counselling students remains our primary role as an office. We counsel students who are in personal or academic difficulty; we counsel international students who have specific needs if they are to come here for schooling and, in many cases, remain here for work or travel. The counselling of international students occasionally overlaps with the former type of counseling for immigration issues often serve as ways to present personal problems. We continue to discuss whether the International Student's Office should remain a part of the SAS, given the range of needs of international students. In a time of ample resources and with clearer commitment to international students we might argue that two offices should be created. In a time of reduced resources and uncertain commitment to meeting the needs within the international community, there is little evidence that such a separation of functions would be in the best interest of international students.

Student visits numbered about 4800 this year. Three thousand international student visits were made to the office. Chinese students, numbering about two hundred, visited repeatedly. On the counselling side visits involved nearly sixteen hundred individuals, many of whom came often. Now that we are keeping records on computers we will be able to be more precise in terms of numbers in the years ahead. As it is these numbers have remained quite consistent through the years. Since its establishment as a separate section of the ODSA the Student Assistance Services has seen from 10 to 15% of the total student body each year. Since each international student visits the office at least once a year, our annual contact is with nearly forty percent of the student community. Although many of the interactions are brief, they help to make this office a barometer for the tone and tenor of the community.

Work with students with disabilities continues to be effective even though the number of such students at MIT is low. In the coming years our numbers can be expected to increase due to less discrimination nationally against persons with disabilities as well as to parental satisfaction with what we have done for students currently enrolled. The families of students with disabilities take a great deal of time to assess support services. MIT does well in this regard, despite minimal financial commitment.

Programs for minority students have been enriched by new staffing. For the first time a Kwanzaa celebration became part of the MIT calendar as did a Hispanic Week. Both were quite successful and new ties have been forged with the OME.

Programs for women students were numerous this year with a good deal of attention given to Acquaintance Rape. This concern links with the issues raised by harassment and makes it likely that we will see major new initiatives in the year ahead to make the campus more hospitable and to hold us more accountable for the environment we foster.

The SAS staff has remained constant for the past year. Ayida Mthembu joined us in July as an Assistant Dean and brought new strengths and experience to the office. It appears that the year ahead will not be as stable on either the staff or support staff level. This is due in part to natural turnover, but it is also due to the high stress nature of the office and the lack of adequate staff and support staff for the growing number of tasks we are expected to assume. We continue to be involved with the medical department in AIDS education efforts and this year we saw our first acknowledged undergraduate AIDS case. We continue to offer staff support to the COD. The task is demanding and sometimes abrasive, but it is done well. Increased INS regulations have intensified expectations in our interactions with international students and, with the anticipated drop in American students, we can expect the number of international students to continue to increase. We have done more with less in this area for so long that we have exhausted whatever play there has been in the system. While, for example, we could certainly use a fax system to see that international students get their documents in a timely fashion we are hesitant to request one for fear we would be unable to respond to the resulting increase in student correspondence.

While the office is fully professional, talented, and extremely hard working, there is serious concern as to whether we can continue to meet the increased demands as in past years.

ROBERT M. RANDOLPH
DANIELLE GUICHARD-ASHBROOK
ARNOLD R. HENDERSON
MILENA L. LEVAK

AYIDA MTHEMBU
LYNN A. ROBERSON
JACQUELINE R. SIMONIS
ANNE ST. ONGE

RESIDENCE AND CAMPUS ACTIVITIES

Undergraduate Housing

This past year has continued to see much activity in the area of undergraduate housing. The number of undergraduates in the Institute Houses in Fall 1989 was 2693 with 93 students living in crowded conditions, about the same in number as last year. During the Spring term, the number of students in the Institute Houses dropped to 2639 with 51 students remaining in crowded rooms.

We were reasonably successful in assigning freshmen to the Houses they requested although there was some difficulty with assignments to some of the older Houses. We were also reasonably successful in granting requests for House-to-House switches and moves into the dormitory system at the end of the Fall and Spring terms. The number of new entries into the Houses increased over previous years, partly because of the need to house students who could no longer live in the Alpha Epsilon Pi fraternity.

Two other significant housing related events this year were the report of the Freshman Housing Committee, which recommended that all freshmen be housed on campus, and the purchase of and license for a lodging house for the Alpha Phi sorority.

Finance Board for Undergraduate Association and Student Activities

There have been dramatic changes this year in the way in which student activity finances are processed. A new accounting software package was introduced this fall and, while it has not automated all record keeping, it does produce detailed information on both MIT and Baybank activity of the individual groups. Turnaround time for most financial recording has gone from a minimum waiting period of a week to almost instantaneous credit recording and issuing of checks. The upgraded methods and procedures have tripled the number of financial transactions in just one year.

Campus Activities

The Campus Activities program of over 200 recognized activities remains strong. The Association of Student Activities, under the leadership of Bill Roberts, approved the charter for a Community Council to resolve disputes and make decisions regarding Institute policies and student activities. In addition, ASA revised the Institute poster policy and held a highly successful IAP leadership conference.

During the presidency of Paul Antico, the Undergraduate Association addressed the issues of proposed academic calendar changes, the student center fourth floor renovations, and the development of a campus shuttle bus. In addition, the UA researched extensively the possible development of a student activity fee.

Through collaboration with student leaders, the Campus Activities Office increased its outreach programming efforts to both activities and living groups. Workshops covered such topics as alcohol education and policy, leadership training, and student life issues. These efforts were once again supplemented with T.I.P.S (Training for Intervention Procedures by Servers of Alcohol) sessions and the IAP IMPACT training workshop on alcohol and drug use.

This year the office took on responsibility for the registration and distribution of parking permits for both undergraduate and commuting students. This represents an increased link with Campus Police that was further enhanced by weekly meetings on campus events in hopes of greater refinement of the party registration process.

Graduate Student Housing

On July 1, 1990, the new MIT graduate student dormitory at 143 Albany St. will open. This facility represents an increase of 186 graduate student beds. We have worked with graduate students in Westgate and Tang Halls as well on a number of issues. Our efforts included a workshop on diversity and several programs on alcohol abuse.

Independent Living Groups

Fall 1989 rush results were about as expected with about 365 freshmen and transfers selecting an independent living group as their residence for 1989-90. An additional 90 women pledged one of the three non-residential sororities. The Panhellenic Council has decided to invite a fourth sorority, Kappa Alpha Theta, to colonize in Fall 1990. Forty-four minority freshmen pledged ILGs, a number close to last year's total and which represented 36% of the incoming minority students.

As a result of sustained effort by MIT, a house was finally acquired for the Alpha Phi Sorority. The property, located at 477-479 Commonwealth Ave., Boston, will house about 60 students and be ready for occupancy by Summer 1991. It will be the first MIT sorority house in Boston.

The Mu Tau Chapter of Alpha Epsilon Pi Fraternity was reorganized by its national office in February. Forty five of fifty-five brothers were given early alumni status and nine of the remaining ten members resigned their membership in protest. This office did not feel the national's actions were justified in this instance and has decided not to grant recognition to a newly reorganized AEPi chapter at MIT at this time. The former AEPi members have reconstituted themselves into Delta Pi Fraternity and have been given provisional recognition by the IFC.

Talbot House

During the year, 64 groups were on the Talbot House schedule, which represents an increase of 10% over last year. However, about 5% fewer people actually used the house, thus revenues were down over 1988-89.

There were four major changes at Talbot House this year: the house was partially redecorated, a new rate structure took effect, meal upgrade options became available, and a new coordinator was brought on board in September.

The new coordinator, Diane Gilbert, '75, has been marketing the house during the "off-peak" seasons to the faculty, staff, and alumni, both for its traditional use as a retreat and as an excellent facility for seminars, off-site meetings, and small conferences.

The major problem facing Talbot House is its depleted capital reserve. Due to rising costs, unexpected and necessary repairs, and the redecorating, the reserves were completely depleted this year. The inspection by Physical Plant revealed no major or minor problems but indicated that asbestos removal might need to be performed around the furnaces and the painting of the exterior should be performed soon.

Future development of Talbot House to make it a more useful and attractive facility for the MIT community could include finishing off the attic to create a Conference/Recreation Room and to landscape the grounds, creating distinct spaces for different activities such as volleyball, field games, and a quiet secluded seating area.

House Fellows Program

The House Fellows Program, under the leadership of Professor James Mar, is now ending the third year of its three year experimental phase. Established in 1987 to promote greater interaction and sense of community between students in Institute Houses and MIT faculty members, the program has expanded from 12 Fellows and 2 undergraduate and 1 graduate dormitories in Fall 1987, to 29 House Fellows in 4 undergraduate and 2 graduate dormitories, and 8 independent living groups. The level of interactions has grown commensurately and assessment of the program through surveys and interviews shows that both student residents and Fellows praise the program and recommend its continuation as it provides a type of interaction between students and faculty which would not otherwise occur at MIT. A formal recommendation will be made to the Office of the Provost to expand the program to include all interested MIT residences.

Discipline and Harassment

In keeping with the desirability for responsible student self-governance in Institute Houses, the Dormitory Council Judicial Committee was formed and training was provided to enable the committee to act as a judicial body for some appeals and initial cases arising from residents in the Institute Houses. This body is expected to play an important role in the disciplinary process at MIT.

This year the RCA staff heard 86 disciplinary cases with an additional 5 cases pending. This number represents an increase over last year caused, in part, by a larger number of graduate student cases. Approximately 400 students were involved in these cases (this number includes witnesses, those bringing the charges, and those charged). Charges in these cases included assault and battery, destruction of property, alcohol and drug abuse, and disorderly conduct. The sanctions ranged from students being required to leave their housing to community service to verbal warnings. A report of student discipline and harassment cases adjudicated by RCA staff will be available in RCA shortly.

Housemasters and Graduate Residents

This year 25 Graduate Residents left their positions in the Institute Houses and the selection process to find replacements is now complete.

The 1989-90 Graduate Resident Orientation Program was structured to improve communications between housemasters and graduate residents. The training program was supplemented by monthly training workshops. Topics for these workshops included suicide, alcohol and substance abuse, AIDS (2 sessions), race and gender, date and acquaintance rape, and relationships.

Monthly breakfast meetings were scheduled with graduate residents to strengthen communications with this office. We also established a graduate resident newsletter which allowed for the dissemination of additional information on a wide range of topics.

We welcomed Professor and Mrs. William Watson as Housemasters of Baker House and Dr. and Mrs. Mark Randolph, and Dr. Alison Hubel and Mr. Gregory Brown as Associate Housemasters of East Campus and Green Hall respectively. Leaving the system at the end of this year will be Professor and Mrs. Tunney Lee, Housemasters, and Dr. and Mrs. Randolph, Associate Housemasters, of East Campus. We are very grateful to them for their significant contributions to the residence system.

Dr. and Mrs. Kenneth Oye of the Political Science department and Dean Ayida Mthembu of the Office of the Dean for Student Affairs have been appointed as the new Housemasters and Associate Housemaster of East Campus respectively.

Staff Changes

Sharon Shea, formerly coordinator of Talbot House, was promoted to the position of UA Staff Accountant, where she replaced Reta Lee who retired at the end of last year. Assistant Dean Andrew Eisenmann has assumed responsibility for the RCA office located on the fifth floor of the Stratton Student Center and has direct reporting responsibility for the UA Staff Accountant and the Staff Associate for Residence Programs.

JAMES R. TEWHEY
NEAL DOROW
ANDREW EISENMANN
STEPHANIE HARRISTON-DIGGS

SUSANNA HINDS
JOHN E. KEEFE
SHARON SHEA

THE OFFICE OF MINORITY EDUCATION

In 1989-90 the Office of Minority Education (OME) sought to further strengthen OME academic programs, increase communication with other offices in ODSA and elsewhere in the Institute, and enhance MIT's effectiveness in the educational process for underrepresented minority students. Staff changes in the course of the fall term resulted in the formation in the spring semester of a new OME team. A series of team-building sessions has served to unify the staff in their commitment to total quality service in the achievement of MIT's overall educational goals. The reception of the new OME team by ODSA and other Institute colleagues, as well as by the minority and general student body, has been excellent and lends hope to our ability to fully meet expectations.

Highlights of major accomplishments and special events are described below. Greater detail regarding these and other activities are available from OME files.

OME Programs

Project Interphase (PI) '90 will be further strengthened due to the successful results of PI '89, the implementation of the small-group learning concept, and the addition of a study skills component. A PI '89 survey conducted by Alberta Lipson, Assistant Dean for Research, indicated a 91% overall participant satisfaction by the 47 students enrolled. The satisfaction index on the part of the PI faculty and staff seemed to parallel that of the students.

The small-group learning concept will be used in both the physics and the mathematics components in PI '90. These, as well as the writing component, will each carry 4 units of credit. Successful completion of the writing component will satisfy Phase I of the MIT writing requirement. Students can also satisfy the MIT swimming requirement as part of the PI physical education component. PI '90 is expected to enroll 53 students, representing a 71% yield from the 75 completed applications. A site visit to two area corporations will add a new element to the academic enhancement components of this 8-week summer residential program for entering first-year students.

Program XL is the newest initiative within the OME. 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 5 or 6 participants meet with facilitators

trained in concept focus and classroom techniques. They work on analytical skills, test-taking strategies, and oral presentations to enhance students' performance in calculus and physics. Data collected by the Assistant Dean for Research indicates that XL has met or exceeded the expectations of the majority of XL students.

During the fall term, 39 students enrolled in XL. Of that number, 36 (or 92%) successfully completed their physics and calculus classes. Support from the Dean of Undergraduate Education enabled XL to be offered in the spring term. It was characterized by similar success rates, illustrating that small-group learning is earning regard at MIT, and making the case for institutionalization of the XL program. Although its initial participants were minority students, we are recommending the use of small learning groups for both minority and non-minority freshmen, beginning as early as the fall of this coming year.

The OME/BSU Tutorial Program (TP) underwent an evaluation that resulted in the identification of a need for fresh approaches to meet the tutoring needs of students. Increased support and cooperation from departments will enable the TP to offer stronger tutoring services to both first and second-year students. Departmental identification of many tutors will reinforce coordination of specific services with faculty teaching the subjects being tutored. An increased number of graduate tutors will enable OME to offer tutoring in requested upperclass subjects. To ascertain if these changes result in an enhancement of services, a student satisfaction study will be conducted in the late fall.

The **Buddy Program** enjoyed a very successful fall implementation. Some 25 upperclass students served as buddies to more than 45 first-year students who requested the service.

Major Activities

The OME was joined by the Office of the Dean for Undergraduate Education as cosponsor of an **8.02 prep class** during the Independent Activities Period (IAP). Pre-sign-up by approximately 60 students rendered an actual participation of some 40 enrollees who wanted the benefit of a "foretaste" of the electromagnetism class.

OME was joined by the Offices of Special Assistant to the President, Graduate School, Career Services, and Student Assistance Services to sponsor the 14th annual **Minority Awards Banquet**. Some 74 underrepresented minority students were recognized for academic achievement of ≥ 4.2 cumulative grade point average. Awards were given for various service categories and leadership activities. Honors were accorded to Dean Shirley McBay and Dr. Clarence Williams for outstanding leadership in achieving minority educational goals.

Other activities sponsored or cosponsored by the OME included a celebration of:

Kwanzaa	Minority Spring Weekend
Black History Month	Martin Luther King, Jr. Day
Buffet Luncheon for Graduating Students of Color and Their Families	
IAP Seminar on social issues concerning the American underclasses	

Research on Minority Student Academic Performance

OME is conducting longitudinal studies of students who participate in Project Interphase and Program XL to assess the long and short-range academic benefits of these programs. A minority student database is also being developed which will integrate data from various offices and departments in the Institute to monitor student retention, attrition, and graduation patterns.

Publications

The OME newsletter was newly formatted and a student contest provided it a name and logo. The first of each month, **SPIRIT: The OME Newsletter** reached the hands of a readership that included some 675 students, faculty, administrative staff, and alumni officers.

Faculty and administrators from nearly 10 MIT offices have held several meetings to plan a **Directory of Services for Underrepresented Minority Students** at MIT. The OME is coordinating the compilation and production of this publication which is expected to be ready by September 1990.

Student Organizations and Committee Involvement

The OME held regular monthly meetings with leaders from the various student organizations that represent OME constituencies (listed below). Through these meetings, OME was able to establish better communication, foster a greater sense of unity and mutual purpose, and promote mutual support concerning educational goals for minority students.

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. OME staff were proud to serve, at the request of the Dean for Student Affairs, on various Institute Committees (listed below). Such committee experience provided for OME staff a valuable perspective on Institute concerns, policies, and procedures, and enabled the "quick start" that the new OME team needed to execute its programs.

Committee on Academic Performance (CAP)
 Committee on Discipline (COD)
 Committee on Student Affairs (CSA)
 Ad hoc Subcommittee on Diversity and Mutual Respect
 Ad hoc Subcommittee on Student Privacy
 Minority Students Interests Group (MSIG)/ Student Arm of MSIG (SMSIG)
 Working Group in Support of Underrepresented Minority Freshmen (WGSUMF)
 Office of Undergraduate Admissions Selection Committee
 Quality Education for Minorities Project (QEM)
 Fenway Retention Consortium

Staff Changes and Personnel Development

Following a national search, Pablo Navarro-Rivera was appointed Assistant Dean/Assistant Director of OME in February 1990 and Gail-Lenora Staton of the QEM Project staff was appointed Assistant to the Director in March 1990 as the result of a local search.

During the three months following formation of the new OME staff, a series of team-building workshops was held. Our objective was to establish an OME *esprit de corps*, and to develop from the team's diversity a synergy that is student-focused. The response to the workshop series has been very positive, and the OME team is poised to meet the educational challenges of the 90's.

FALL 1989 ENROLLMENT STATISTICS FOR UNDERREPRESENTED MINORITY UNDERGRADUATES

	Native American	Black American	Mexican American	Puerto Rican	Minority Total	All Students
Undergraduate	19	272	163	86	540	4,307
% Min.Enroll.	3.5	50.3	30.2	16.0	100	12.5
% Total	0.4	6.3	3.8	2.0	12.5	

JUDY J. PITTS
 ALBERTA LIPSON
 PABLO NAVARRO-RIVERA
 GAIL-LENORA STATON

Facilities Use

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; Susanna Hinds, Director of Campus Activities; Doreen Morris, Assistant to the Provost and the Senior Vice President; Mary Morrissey, Director of the Information Center and Special Events; Patricia Murphy, Administrative Assistant, Campus Activities Complex; Ron Suduiko, Assistant to the President for Government and Community Relations; and Phillip Walsh, Director, Campus Activities Complex.

During the 1989-90 year, in addition to a number of smaller meetings, the Institute hosted the Governor's Economic Summit, the thirty-ninth Pugwash Conference on Science and World Affairs, the Silicon Epitaxial Growth for Integrated Circuits Conference, the Sloan Fellows Alumni Convocation, the meeting of the Association of American Universities Data Exchange, the ACM Conference, the annual meeting of the New England Intercollegiate Soccer Officials Association, a conference on Integrating Safety and Waste Management Practices at Research Facilities, a joint conference of the Semiconductor Safety Association and the Campus Safety Association, the annual meeting of the American Junior Classical League, a lecture by the SYDA Foundation, a meeting of the Massachusetts Immigrant and Refugee Advocacy Coalition, the commencement exercises of Boston Tech and Boston Latin high schools, the Second International Conference on Semi-Solid Processing of Alloys and Composites, a joint project with the J.W. Hennigan School and the Learning and Epistemology Group, a conference in honor of Prof. John Elliott's 70th Birthday, and a teacher-training program by the Museum Institute for Teaching Science.

In addition to the above listed typical facilities use requests, the Facilities Use Committee together with the Provost's Office, is frequently drawn into issues involving proposals for controversial use of MIT space. As a result, the Office of the Provost is often consulted on a wide range of political, social, and religious issues stemming from questions about facilities use.

Issues raised during FY '90 included the policy on construction of theatrical sets in classrooms, the use of Lobby 10 and the Infinite Corridor Panels, the review of the current facilities scheduling process, the proposed ASA Code Of Conduct, and the coordination of art projects in public spaces.

Stephen D. Immerman

Associate Provost and Vice President for Research

Francis Bitter National Magnet Laboratory

The Francis Bitter National Magnet Laboratory (FBNML) operates with core support from the National Science Foundation (NSF) to provide dc high magnetic field facilities, free of charge, to qualified scientists throughout the United States. A facility for generating pulsed magnetic fields of 5 to 10 ms duration is also operated on an experimental basis. The Laboratory can produce a world record steady field of 31.8 tesla (T) in a 33 mm bore, as well as pulsed fields up to 68.4 T of duration >5 ms. 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.

Core support for the Laboratory operation is provided by a cooperative agreement with the NSF, which is subject to peer review and renewal every three years. As a result of the renewal process in 1985, funds for in-house research were eliminated. In the renewal proposal submitted in 1988, we requested funds to resume in-house research, to develop a pulsed field facility, to design a 45 T hybrid magnet, to begin construction of a 750 MHz (17.5 T) NMR magnet, and to replace our 10 MW motor-generator power supply with a 24 MW solid state one. Funds were not provided in response to most of these requests. We strongly believe that in-house research is an essential component of a successful national facility, and were pleased that NSF allowed us to resume limited support for appropriate in-house research.

CURRENT DEVELOPMENTS

Several important administrative changes have taken place in the Laboratory during the past year. Effective July 1, 1989, Dr. Simon Foner was appointed Associate Director of the Laboratory. While he will be involved in all important decisions about Laboratory management, Dr. Foner's special area of responsibility will include the development of the means of generating pulsed magnetic fields and their use in research. This appointment recognizes the important role that Dr. Foner has played in the activities of the FBNML.

Dr. Robert Griffin, a Senior Research Scientist in the FBNML, was appointed Professor in the MIT Department of Chemistry, effective September 1, 1989; this reflects his widely recognized contributions to nuclear magnetic resonance in solids. Professor Griffin will continue to be involved in Laboratory activities, and has been appointed Associate Director with the special responsibility to provide leadership for NMR magnet development and related research activities in the Laboratory.

Facility development has continued, within the limits of our resources, during the past year. Magneto-optical experiments now represent a significant fraction of the total high-field magnet time. The majority of this use relies on optical fibers to access the small-bore cryostats. As a result of pioneering work with fiber optics at the FBNML, we can provide users with the facilities for optical experiments in higher fields and at lower temperatures than any other laboratory. For example, Raman scattering measurements have been made to fields of 30 T and temperatures down to 0.1 K. The Laboratory also offers facilities for optical measurements in the 60 T pulsed-field magnet. Two radial access magnets (11 T and 17 T) are equipped with a conventional optical dewar for routine measurements in the visible and near-infrared regions. For higher fields, low-loss silica cables send light between the optical equipment and the 19 T, 23 T, and 30 T dc magnets, as well as the Laboratory's top-loading dilution refrigerator. Spectral analysis is provided by a

high-resolution double-grating spectrometer, or a mobile triple spectrometer equipped with a charge-coupled device multichannel detector.

Apparatus for high-resolution temperature-controlled magnetic birefringence studies in fields to 20 T has also been constructed. The first application of this facility has been to study the effects of high magnetic fields on microemulsions and "colloidal" smectic liquid crystals. During the coming year, construction of an apparatus for quasi-elastic light scattering in high magnetic fields will be completed. Both the incident and scattered light will travel through optical fibers, and a digital autocorrelator will be used for spectral analysis of the scattered light.

The Laboratory's venerable DEC "MINC" minicomputers used for data acquisition in the high-field magnet cells have been replaced with three Macintosh II computers. It is easy to modify the data acquisition program to control different instruments. This is intended for users who do not have a particular commitment to their own laboratory data acquisition system. Many users are accustomed to one or more of the software packages and interface cards which work with IBM-PC compatible computers, and the laboratory has this type of hardware available. A workstation with advanced graphics capability has just been ordered for the Laboratory; it will be especially useful for analysis of the output data from scanning tunneling microscopes used in high magnetic fields, and should be very helpful to our magnet design group.

Work has continued on the development of Hybrid III, which will consume much less He and should produce 35 T in a 33 mm bore. We have entered into a collaboration with Toshiba Corporation to produce monohelix inserts for this magnet. In this collaboration, Toshiba will provide materials and manufacturing techniques for the inserts, and FBNML will carry out the analytical work related to the design. There will also be experimental work to measure the strain in an insert operating in our present hybrid. In this way, we expect to obtain the water-cooled component of the new hybrid at a relatively low cost. The coils for the superconducting background field of 13 T have been wound, the cryostat is being tested, and the magnet should be operational around the end of 1990.

PROPOSAL FOR A NEW NHMFL

In 1985 the NSF appointed a panel of distinguished scientists to advise upon the future course of high magnetic field research in the United States. In its 1988 report, the high field panel concluded that many important scientific problems required high magnetic field studies for their solution, and recommended that a new National High Magnetic Field Laboratory (NHMFL) be established. The NHMFL would have improved capabilities and the site would be chosen after a nationwide competition.

Proposals were solicited in the fall of 1989, with letters of intent due February 1990 and the full proposal due May 1, 1990. Accordingly, much of the Laboratory's effort for the past year has gone into preparing a proposal to establish the NHMFL at MIT, based upon the existing laboratory. Key features of our proposal include the following.

dc High Field Facility

This facility will incorporate the following features:

- Four 6 MW current-controlled solid state rectifier power supplies. The power supplies will be able to support operation of one 24 MW magnet, or will be able to operate simultaneously as many as four smaller magnets.
- A total of 23 water-cooled magnets and four hybrid magnets installed and available for daily use. Of these, 17 will achieve fields greater than 21 T. There will be one hybrid capable of 35 T, another will be designed to achieve 45 T, and a second 45 T hybrid is planned for the second five year period of the NHMFL.
- The magnets will be located in 15 experimental cells, with the full 24 MW of power available in four cells, and 12 MW supplied to the remainder.

Pulsed Field Facility

Many experiments require fields exceeding those available from dc magnets and therefore we proposed a NHMFL which would provide a pulsed field facility whose capabilities fall into two broad classes:

- A "long pulse" facility which can generate pulses of from 5 to >20 ms half-period and peak amplitude >70 T in wire-wound magnets with bores from 1.5 to 3.0 cm.
- A "short pulse" facility which can provide single shot pulses >200 T in amplitude and from 2 to 10 ms in duration.

NMR Magnet System

Higher fields offer many advantages for nuclear magnetic resonance (NMR) studies of molecules in solutions and in solids. The FBNML is completing the installation of an NMR magnet with a field of 14.1 T, which gives a proton resonance frequency of 600 MHz. With support from Kobe Steel Corporation, the Laboratory has embarked upon a project to build a 750 MHz system. This program would continue as part of the NHMFL program, and we proposed fabrication of an 850 MHz magnet which can readily be modified to 1 GHz when suitable superconducting materials for the highest field winding become available.

Supporting Facilities

Suitable instrumentation for NHMFL users to take advantage of these facilities was included as part of the proposal. The most sophisticated equipment for dc field research would be provided by five "supporting facilities" which would be developed in the course of an internal research program. These five facilities would be:

- Low temperature studies ($T < 1$ mK).
- Optics (also useful for pulsed fields).
- Complex fluids (light scattering and magnetic birefringence).

- Magnetometry.
- Nanovolt measurements and small structures.

In-house Research

The high field related internal research which was proposed for core support from the NHMFL was organized into five programs:

- Quantum-confined systems of electrons.
- Superconductivity and high magnetic fields.
- High field properties of semiconductors.
- High field investigations of complex fluids.
- Low temperature physics in high magnetic fields.

There will also be a strong program in NMR research, based substantially on existing programs supported by the National Institutes of Health (NIH), which will use the NMR magnets and spectrometers proposed to be developed by the NHMFL.

Materials Development

Magnet development is currently restricted by the performance of the available materials. We need to have improved properties in the following three areas: (1) high strength, high conductivity metallic conductors; (2) superconductors that tolerate higher magnetic fields; (3) insulating materials that will stand up to higher electrical, mechanical, and thermal stresses. Our proposed NHMFL has a materials development program to be undertaken in collaboration with several national laboratories.

Outside Interactions

Increasing the bonds between the FBNML and the remainder of the MIT campus through increased participation of faculty in the internal research program of the FBNML has been a goal for some time. Our proposal for the NHMFL requests support to involve nine MIT faculty from seven departments, five faculty from other Boston area universities, and four senior FBNML staff in the in-house research.

EVALUATION OF PROPOSAL

The process to evaluate the proposals to establish a NHMFL has several stages. The first stage was a mail review of the proposals by ten experts. MIT's proposal was very strong technically, and received very favorable mail reviews. A site visit by a panel of experts took place on June 25, 1990. Recommendations for action will be made to the NSF by the Materials Research Advisory Committee (MRAC) of the NSF Division of Materials Research, based upon reports from the mail reviews and site visits of the competing proposals. The MRAC will meet in July, and the NSF is expected to present its decision for approval at the August meeting of the National Science Board. The FBNML management believes the MIT proposal is the strongest scientifically

and technically by a significant margin. Some uncertainties remain. Cost sharing has been said by the NSF to be an important issue; MIT's cost sharing is both substantial and generous, but may not satisfy the NSF. It is also not yet clear whether the NSF is prepared to supply the resources necessary to establish a leading high magnetic field laboratory. These questions should be answered by the time of our report next year.

J. DAVID LITSTER

Center for Cognitive Science

INTRODUCTION

The academic year 1989-90 was 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 is currently in transition and will be replaced by Project Athena resources in the 1990-91 academic year. The situation will be assessed periodically during the coming months, primarily 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.

The funding saved by these switch-overs will be 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 successful seminar series of invited speakers. An edited volume of last year's seminars was published under the auspices of the Center for Cognitive Science and plans are underway to do the same with the second year's seminars.

The computational facilities for the project have been nearly completed. Several Macintoshes provide a hardware platform for personal Lisp workstations, while Cogito acts as a file server. During the past year, the Project acquired a large, million-word English corpus to serve as a test bed for various hypotheses about lexical semantics. A general-purpose morphological front end parser was completed, as well as a statistically-based lexical disambiguator. These components will serve as tool-kit "black boxes" that can be used in every future parser design.

The Lexicon Project

The other major research project in the Center is the Lexicon Project. The work being done in this project has two aspects, one descriptive, the other theoretical. Descriptively, the Project has been collecting and documenting the lexical resources of three Non-Indo-European languages, namely: Tamazight Berber (Morocco), Warlpiri (Central Australia), and Winnebago (Wisconsin). This phase of the work has come to a close for the moment while the theoretical phase continues. The Project is involved in the general effort within theoretical linguistics to deepen understanding of the lexicon, a topic of crucial importance in understanding human language abilities. English and other well-known languages figure prominently as objects of this research, as do the Non-Indo-European languages mentioned above. This work is, therefore,

largely comparative and seeks to elaborate a general theory of the lexicon and its relation to other components of grammar.

During the four years of the Project, work has continued on the implementation of a framework that will allow us to build a computer-based database for English verbs. This database will contain information about the properties of verbs that will form a foundation for further work on lexical semantics and the construction of a lexicon complementing the work on parsing being done at MIT. As part of this effort, the Lexicon Project is compiling a set of resource materials on English lexical organization, focusing on verb classification and diathesis alternations, which will be put out in the Lexicon Project Working Papers series.

PROGRAMS FOR VISITORS

The Visitor Selection Committee

During the academic year 1989-90 the Center sponsored five visiting scientists.

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.

SEMINARS AND COLLOQUIA

During the 1989-90 academic year the Center continued to support four kinds of seminars. The Center for Cognitive Science Seminar Series, a monthly seminar, is open to the community at large and presents 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 500 members of the community attended a total of 7 seminars. Second, the Lexicon Project conducts fortnightly meetings on topics about the structure of the lexicon. These meetings are attended by approximately 200 scholars from a number of MIT departments and other institutions in the area. Third, the Center has initiated the Parsing Project seminar, attended on a fortnightly basis by scholars from MIT and other institutions. The fourth seminar is the Philosophy and Psychology discussion group, consisting of philosophers and psychologists from MIT, Harvard, and Tufts who meet on a monthly basis to explore topics of common interest.

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 37 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, 36 papers have been published.

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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.

IN MEMORIUM

Finally, the Center notes with great sadness the untimely death on July 10, 1989 of Dr. Josie White Eagle. A member of the Winnebago Tribe, Dr. White Eagle received her doctoral degree from the Harvard School of Education and, as a member of the Lexicon Project, had been working intensively on a descriptive lexicon of Winnebago. Part of her results appeared in "The Lexical Study of Winnebago", a Lexicon Project Working Paper. She was an indefatigable researcher, an invaluable colleague, and a warm friend who is missed.

SYLVAIN BROMBERGER
SAMUEL JAY KEYSER
STEVEN PINKER
Co-Directors

Center for Materials Science and Engineering

Many engineering systems and devices in today's technology are limited by the quality or properties of available materials. Conversely, the discovery of new materials with improved properties can give rise to new industries. The condensed matter sciences continue to provide intellectual challenge and unanticipated surprises: quasicrystals, the quantum Hall effect, and oxides that superconduct at high temperatures are very recent examples of unanticipated discoveries that took the materials community by storm and captured the imagination of the press. Given the pace of change and the importance of materials in many aspects of science and technology, it is not surprising that the studies of several commissions and panels have identified materials as an area ripe for exploitation and as a source of opportunities to enhance national competitiveness. The opening lines of the preface of the National Research Council report, *Materials Science and Engineering for the 1990's*, states that its study ". . . revealed a field of great vitality—rapidly emerging scientific discoveries, stunning new capabilities for understanding and prediction, and applications that are essential for the health of every U.S. industry."

Similar feelings, far ahead of their time, led to the establishment of the Center for Materials Science and Engineering in the early 1960's. During this period, the notion of a science or of an engineering of materials that transcended different classes of materials and the industries based thereon had just begun to emerge. The Advanced Research Projects Agency (ARPA), convinced that it was necessary to expand the level of national effort in materials research, and to increase the number of students receiving interdisciplinary graduate training in such areas, established a system of Interdisciplinary Laboratories (IDL's), as they were then termed, at selected research universities. Central to the concept of the IDL's was the notion that if progress was to be made on many critical materials problems it would be necessary to foster interdisciplinary collaborations that combined the viewpoints and backgrounds of many traditional departments of science and engineering. Few workers today in materials-related areas would disagree with that assessment. Support for the IDL's was assumed by the National Science Foundation (NSF) in July 1972 under the Materials Research Laboratory (MRL) program of the Division of Materials Research. The substantial block funding committed to the MRL program had three objectives: funding for coordinated, multi-investigator projects in "major thrust areas" (thereby defining a term used in this and earlier reports) and use of "seed funding" for support of junior faculty or established faculty who were initiating work of relevance to a thrust. Programs of both sorts were viewed as being difficult or unfeasible under the traditional single-investigator mode of NSF support. As a third part of its charter, funds were provided to the MRL's for the establishment and operation of major central research facilities. A unique feature of the MRL program is the significant local autonomy that is delegated for planning and management of programs. This serves to maximize the effectiveness of the block funding as the MRL's are able to utilize effectively faculty and institutional resources, and can act quickly on new research opportunities.

Seven years ago, after major review, NSF reduced the 14 existing MRL's to the present group of nine, of which the MIT Center for Materials Science and Engineering is second largest. This action allowed adequate support under a total MRL budget that had grown increasingly constrained. CMSE continues to receive virtually all of its support through the MRL program. This funding has proved stable over the last several years, but has remained constant (or nearly so) as other newly-created materials programs that are block funded compete for resources. Budgetary limitations have continued through the period of the present report and represent the primary limitation on the establishment of programs in emerging areas that we view as important.

CMSE supported research in four areas-of-thrust during the year just concluded. The research centered on themes that ranged from the fundamental science of phase transitions or the mechanism of superconductivity to the efforts of a team that examined the mechanical properties of intermetallic compounds that have realistic potential for engineering application in gas turbine engines. An overview of the research in each of these four areas-of-thrust, along with the names and departmental affiliations of the principal investigators, is provided in the following sections. Descriptions of the individual projects are included in *Research in Materials, Annual Report*, compiled and published by CMSE on behalf of the broader materials community at MIT.

Sixteen seed projects were funded in 1989-90, an increase of two above the preceding year. The principal investigators of 11 projects were junior or recently-appointed members of the faculty; 7 of the 16 seed projects were in areas deemed relevant to ongoing thrust area research. In aggregate, CMSE supported thrust area and seed projects for 42 principal investigators drawn from eight different departments--on the order of one-third of the departments that exist at MIT. The research projects directly funded by CMSE through NSF/MRL support represent approximately 25 percent of the materials research performed at MIT. CMSE provides further indirect support, however, through the

operation of its central research facilities. These laboratories are available to qualified users throughout the entire MIT community, as well as to sister institutions when capacity sufficient to accommodate their work is available. CMSE operated 13 central facilities during 1989-90. Some of these laboratories provide basic services such as chemical analyses and machining, but most involve state-of-the-art and often unique apparatus that is too expensive to be acquired and maintained 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 influence on the research performed at MIT which extends well beyond the projects that it is able to support directly. Indeed, during 1989-90, on the order of two-thirds of the activity in our central facilities was associated with non-CMSE-supported projects. A following section highlights recent modifications and additions of apparatus within these facilities.

The interdisciplinary flavor of the research that is conducted within CMSE provides exceptional opportunities for the training of undergraduate and graduate students. In 1989-90 CMSE provided financial support for 28 semesters of UROP activity for 24 students registered in six different academic departments. Approximately half of the principal investigators of CMSE-supported projects were involved in the supervision of a UROP student.

Faculty participate in the administration of CMSE in two ways. All changes in CMSE policy, as well as specific approval of seed proposals, equipment requests, and space changes, are made after discussion and recommendations proposed by an Internal Advisory Committee. This group is composed of the faculty members who serve as leaders of the thrust area research programs, plus additional faculty selected as members at-large to ensure balanced representation from departments that are involved in CMSE programs and from key central facilities. During 1989-90, the members of the Internal Advisory Committee consisted of Professors Samuel Allen, Ali Argon, Robert Cohen, Carl Garland, Marc Kastner, David Litster, Robert Silbey, John Vander Sande, and Mark Wrighton. Faculty, secondly, participate in the supervision and operation of the central facilities. Each laboratory has 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. We find that our facilities work best when overseen by a faculty member with strong interests in instrumentation, coupled with a vested interest in assuring the state-of-the-art capability and smooth operation of the facility to the benefit of his or her own research programs.

The Center, largely through its central facilities, presented a number of minicourses and Independent Activity Programs designed to introduce students to the capabilities and operation of the instruments that they house. The Center provided partial support for a condensed-matter seminar series coordinated by the Department of Physics. One of the features of that series was an all-day symposium organized by Professor Nihat Berker that highlighted the research on structured fluids that is conducted by members of our Phases and Phase Transitions Thrust. CMSE operates a weekly colloquium series, which is traditionally held at noon on Fridays. During the spring semester of 1990, the Center instituted an experiment that, in view of its great success, may be repeated in future years. Rather than inviting speakers from other laboratories to visit MIT and present talks (or, more customarily, snaring travelers as they pass through Boston), the spring colloquium series instead featured presentations by each of the investigators participating in our Synthesis and Properties of Novel Polymers Thrust. This thrust was selected because its highly interdisciplinary composition causes the participants to be scattered through the far reaches of the Institute. The funding that would ordinarily have been used to pay travel expenses for visiting speakers to be present for but a brief period before and after their presentations was instead lumped into a single sum to permit bringing a world-class researcher to campus for a more extended and relaxed period of time. The individual who was enthusiastically selected by members of the thrust, Dr. Helmut Ringsdorf, Professor of Organic Chemistry at the University of Mainz, was designated as the first Distinguished Visiting Scholar of CMSE and was in residence at MIT for the better part of a week in early May, 1990. Professor Ringsdorf presented a series of three lectures that addressed polymer science as an interface between materials science and life science—a molecular engineering of functional supramolecular systems. During his period of residence Dr. Ringsdorf made himself available for meetings with faculty and graduate students and, indeed, every available moment of his time during day and evening was fully subscribed. The enthusiasm with which Professor Ringsdorf engaged in these interactions made him an ideal choice for the first such arrangement.

Yet another way in which CMSE serves the broader community at MIT is through assuming responsibility for coordinating, assembling, and publishing interdepartmental annual reports. These include *Research in Materials* (over 400 pages in 1990) and *Polymer Research Annual Report* (125 pages). These publications provide focus and showcase for the full range of materials research performed at MIT and receive wide distribution.

PERSONNEL CHANGES

The preceding year (1988-89) had witnessed a change in CMSE Director and a complete turnover in the headquarters administrative staff. The past year was one of more characteristic stability as the new administrative staff evolved into an effective, integrated team. In keeping with newly assumed responsibilities, Susan G. Rosevear was promoted to Publications Coordinator. Edward A. Jacobson was appointed as Accounting Assistant at the end of October 1989, to fill a vacant position.

Changes in the research staff of CMSE included the following appointments and resignations. Among Research Specialists associated with CMSE central research facilities, Dr. Song Chun-Li resigned as supervisor of the Rapid Solidification Facility as of February 28, 1990, upon completion of his scheduled tenure. Dr. Gerald Swislow, who provided valuable part-time assistance in completing software development at the Synchrotron Radiation Facility at Brookhaven National Laboratory, resigned on February 18, 1990, upon completion of his pre-arranged period of service. After a long search, Joseph D. Peidle was hired on August 14, 1989 to participate in the completion of the construction of instrumentation on the beam line. Mark Cooper resigned from the Central Facility for Crystal Growth on July 7, 1989 to assume a position in industry. Many of his responsibilities were assumed by Dr. Mark H. Garrett, who was subsequently appointed as a postdoctoral associate on August 10. Kazuyoshi Kuriyama received an appointment as Visiting Scientist in the laboratory of Professor Mildred Dresselhaus on July 10, 1989; Hervé Blanck left MIT on May 31, 1990, upon completion of his intended visit. Timothy McClure on December 4, 1989, assumed a position as Senior Technician in the Microelectronics Central Facility, filling a position from which Darrel Roan had earlier resigned in order to return to school.

CURRENT RESEARCH

The following sections present brief descriptions of the general nature of the research and faculty participants and their departmental affiliations for each of the four research Areas-of-Thrust supported by CMSE during 1989-90, as well as brief mention of the single-investigator seed grants that were funded during this period.

Transition Metal Oxides

Research in this thrust area was initiated shortly after superconductivity at elevated temperatures was first discovered in lanthanum copper oxide. Important contributions to early developments in this field were made by the researchers in this thrust as a result of the successful growth of the first large single crystals of La_2CuO_4 in our Central Facility for Crystal Growth. MIT continues to be one of the small number of institutions in the world where large single crystals of these lamellar copper oxides are successfully grown. Availability of single crystals enables two sorts of studies that provide important insights into the mechanism of superconduction. The first is the use of neutron scattering to study the correlations among the magnetic moments on the copper ions. The second is the ability to measure the dependence of optical and transport properties on crystallographic direction. The neutron scattering studies of Professors Robert Birgeneau and Marc Kastner have demonstrated that the mobile holes induced by Sr doping drastically disrupts the antiferromagnetic alignment of the Cu moments. The temperature above which the magnetic moments disorder drops precipitously with strontium doping or excess oxygen content, and the long-range order in the arrangement of magnetic moments is completely destroyed when more than 1 percent strontium has replaced lanthanum. For large strontium additions (one percent to three percent), there are short-range antiferromagnetic correlations that are commensurate with the crystal lattice and which have a correlation length equal to the distance between the doping-induced holes. The integrated intensity of the neutron scattering suggests that the Cu^{2+} moments are preserved in the superconducting materials as in the undoped material. Recent work has shown that the antiferromagnetic correlations in the superconductor are incommensurate with the crystal lattice. Another surprise has been the discovery of a pseudo-gap in the spin excitation spectrum that opens at a temperature much higher than the critical temperature for the superconducting transition. Another approach to examining anisotropy is the study of materials fabricated in the form of highly-oriented thin films. Work of this sort has been pursued by Professors David Rudman and Terry Orlando with materials in the Bi-Sr-Ca-Cu-O family. Superconductors prepared in this form also have potential for application in devices such as DC superconducting quantum interference devices (SQUIDs), which are extremely sensitive detectors of magnetic fields. The thrust has indeed fabricated the first known SQUID from sputtered films of the Bi-containing superconductor to produce devices that displayed extremely low flux noise. Professor Yet-Ming Chiang has investigated alternate processing routes for the preparation of thin films in this system, namely through the spin coating and pyrolysis of liquid citrate precursors.

Participating faculty and departmental affiliation: Professors R. J. Birgeneau, M. A. Kastner, P. A. Lee (Physics); M. S. Dresselhaus, T. P. Orlando (Electrical Engineering and Computer Science); Y.-M. Chiang, D. A. Rudman, H. L. Tuller, and J. B. Vander Sande (Materials Science and Engineering); and H. P. Jenssen (CMSE Principal Research Scientist).

Phases and Phase Transitions

This group attempts to gain insight into the behavior of condensed phases and the properties of materials in the vicinity of order-disorder phase transitions. Attempts are further made to employ statistical mechanics to develop theoretical models that describe their behavior. The group is one of the strongest in this field. The research involves the study of structured fluids: liquid crystals, micelles, microemulsions, and gels. The experimental techniques used to study the transformations include precise calorimetry and scattering studies that employ light, x-rays, and neutrons as probes. Professors Birgeneau, Garland, and Litster have carried out for a number of systems detailed studies of phase transitions in a smectic liquid crystal that involve the melting of a one-dimensional wave in a three-dimensional liquid. Measurements of properties such as heat capacity, elastic constants, and correlation lengths all obey the expected scaling laws, but with exponents that differ from those expected for an ideal transition. Professors Birgeneau and Litster have found it possible to grow high-quality crystals of smectic-I crystals in the form of free-standing films with thicknesses that range down to as few as five molecular layers. It is well known that true long-range positional order can occur only in a three-dimensional solid. In two dimensions the order must decay to zero over large distances. These high-quality crystals provided an opportunity to test both the thickness and mechanism whereby the behavior crosses over from that of a three-dimensional to a two-dimensional solid. The shape of x-ray diffraction peaks showed that only the 1000-layer film behaved in the traditional three-dimensional fashion. Professor Mehran Kardar has developed a theoretical model for tethered surfaces that predicts transitions between flat, crumpled, and compact phases of such networks. In collaboration with Professor Toyochi Tanaka, such surfaces have been realized experimentally by oxidizing graphite into very thin sheets. Professors Kardar and Tanaka have also collaborated on the interpretation of the complex patterns observed on the surfaces of swelling gels. Professor Sow-Hsin Chen has used small-angle neutron scattering to show that the structure of protein surfactant complexes in solution is quite different from the traditionally assumed structures. Professor Daniel Blankschtein has shown that measurements of the osmotic pressure of micellar solutions yields a weight average rather than a number average of a micellar molecular weight. This required reinterpretation of available data for aqueous solutions of nonionic surfactants in terms of the presence of elongated rod-like micelles that can grow, rather than the small, monodisperse, globular micelles that had been the generally accepted model.

Participating faculty and departmental affiliation: Professors C. W. Garland (Chemistry); G. B. Benedek, A. N. Berker, R. J. Birgeneau, J. D. Litster, T. Tanaka (Physics); and S.-H. Chen (Nuclear Engineering).

Synthesis and Properties of Novel Polymers

Faculty from four departments collaborate in this thrust in the creation of novel polymers and in the investigation of the electrical and mechanical behavior of these materials. Professor Richard Schrock of the Chemistry Department had earlier developed a unique synthesis route whereby transition metals are used to catalyze a ring-opening metathesis reaction. The product is unusual in that control of the reaction permits production of a polymer of precisely-defined chain length. In a collaboration during the past year, Professors Schrock, Cohen, and Silbey have produced block copolymers containing lead. Upon treatment with H₂S, small clusters (20-40 Å diameter) of PbS were produced. The sulfide usually absorbs all visible light and appears black, but the absorption edge moves into the visible region when the size of these "quantum dots" is in the range of tens of Ångstroms. The polymer films which have been produced thus are red, yellow, or orange and have potential for use in nonlinear optical applications. Professor Michael Rubner has fabricated multilayer Langmuir-Blodgett thin films comprised of electrically conductive polymer layers of molecular thickness, alternating with insulating layers. These molecularly-engineered thin films exhibit unusually large dielectric constants and highly anisotropic electrical conductivities, conduction within the plane of the multilayer structure being over a million times greater than conductivity across the film thickness. The properties of these multilayer films could conceivably be exploited to create thin-film capacitors with large energy-storage capabilities.

Participating faculty and departmental affiliation: Professors R. R. Schrock, R. J. Silbey, M. S. Wrighton (Chemistry); R. E. Cohen (Chemical Engineering), M. F. Rubner (Materials Science and Engineering); and A. S. Argon (Mechanical Engineering).

Intermetallic Compounds at High Temperature

Six investigators from the Departments of Materials Science and Engineering and Mechanical Engineering performed experimental study of the processes and mechanisms that govern high-temperature deformation and fracture resistance. Selected for investigation are structural materials that are prominent candidates for high-temperature applications, as increasingly higher operating temperatures provide an effective route to improved performance of power generation systems and aircraft turbine engines. The emphasis in research is on multiphase intermetallic compounds. During the past year, Professors Allen, Argon, and David Parks have examined the origin of the remarkable creep resistance of nickel-aluminum superalloys. It was found that the ordered cuboidal Ni₃Al phase, which constituted about two-thirds of the volume of the alloy, did not deform at temperatures to 900°C; the entire deformation occurred in the disordered gamma phase. The high creep resistance of this highly regular microstructure results from the high stress necessary to bulge dislocations through narrow channels in the gamma phase, as well as being partly due to low diffusion coefficients and the retention of dislocations to neutralize thermal misfit between the two phases. This rather thorough understanding of the sources of creep resistance serves as an important basis in attempts to understand the cyclic deformation behavior of these superalloys. Professors Allen and Frank McClintock have collaborated in relating the inelastic properties of NiAl to dislocation arrangements in deformed crystals of the material. The cyclic straining response and electron microscopic observations of dislocation arrangements were combined to a model that predicts the rate and temperature dependence of the inelastic response of this material, which is a promising heterogeneous high-temperature alloy and also a material that sees application as protective coatings for turbine blades.

Participating faculty and departmental affiliation: Professors S. M. Allen, R. M. N. Pelloux (Materials Science and Engineering); A. S. Argon, L. Anand, F. A. McClintock, and D. M. Parks (Mechanical Engineering).

Seed Research

Seed funding is provided to support the ideas of newly-appointed faculty members or projects that are initiated with the expectation that they may be eventually incorporated into one of the Areas-of-Thrust. Support is, in some cases, provided for a feasibility study or for a novel idea that holds great interest and promise, but also involves some risk. The normal process of peer review is not really geared to handle proposals of this nature, and they would likely not fare well. During 1989-90, two previously approved seed projects were brought to completion. Among the projects initiated by recently-appointed Assistant Professors, Professor Jesus del Alamo will push existing capabilities for lithography to the limit in an attempt to fabricate fine-scale structures that may display quantum tunneling. Such effects are of fundamental interest, but may also provide a basis for design of devices. Professor Peggy Cebe has used calorimetry and scattering as probes to examine the behavior of the rigid, amorphous component of polymers. A sputtering system constructed by Professor Manuel Oliveria will allow the fabrication of magnetic materials with fine-scale microstructure. Professor Hans-Conrad zur Loye, a solid-state chemist, has attempted to synthesize new layered oxides that are related to materials presently known to display high-temperature superconductivity.

Participating faculty and departmental affiliations: Professors B. Altshuler, J. M. Graybeal, T. Greytak, M. Kardar, S. Mochrie (Physics); D. Blankshtein (Chemical Engineering); S. L. Buchwald, H.-C. zur Loye (Chemistry); P. Cebe, N. Herbots, L. W. Hobbs, M. Oliveria, E. L. Thomas, C. V. Thompson (Materials Science and Engineering); J. del Alamo (Electrical Engineering and Computer Science); and J. S. Haggerty (Senior Research Associate, Materials Processing Center).

CENTRAL FACILITIES

During 1989-90, CMSE operated thirteen laboratories as central research facilities. These laboratories were available to all qualified users in the MIT community. State-of-the-art apparatus that had been recently acquired became fully operational in certain facilities during 1988-89. Acquisition and installation of a new transmission electron microscope is another noteworthy development.

CMSE operates a Synchrotron Radiation Facility jointly with IBM at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory. During the past year, NSLS resumed full operation. In addition, instrumentation was completed on the third beam line at our installation. The facility has state-of-the-art instrumentation. In typical experiments a two to three order-of-magnitude increase in counting rates is achieved relative to those available from even a high-intensity rotating anode x-ray source. Work is planned to upgrade the sample chambers to an ultra-high vacuum capability in the future.

Last year saw the Central Facility for Surface Analysis, operated in collaboration with Harvard University, come into full operation. The facility includes a General Ionex Tanditron Accelerator for Rutherford backscattering analysis and a Surface Science Labs Kevex SSX 100 x-ray photoemission spectrometer (which reside at Harvard), plus a Perkin Elmer Model 660 scanning Auger microprobe and a Vacuum Generators Model 1X70S SIMSLAB for secondary ion mass spectroscopy (housed within CMSE). This equipment has already experienced extensive use.

The Central Facility for Scanning Transmission Electron Microscopy and Transmission Electron Microscopy previously contained four TEM instruments, two of which were approaching 20 years of age and no longer could supply the requirements of any but an occasional user. These two older instruments were sold and replaced during 1989-90 with a single state-of-the-art microscope. An ISI/Akashi EM002B TEM, operated at 200 KV, was installed during the past year. This is the first of a new series of high-resolution instruments of advanced design. It is capable of 1.8Å point-to-point resolution and has demonstrated 1.25Å line-to-line resolution. The facility awaits delivery of a Vacuum Generators HB603 field emission STEM, one of the first of a new line of instruments that operates at 300 KV. Its modern lens design will allow the formation of electron probes less than 2Å in diameter. The higher operating voltage reduces beam spreading and should thereby permit quantitative analysis at a 3Å scale. Delivery of this substantial improvement to the capability of the facility is expected at the end of 1990.

BERNHARDT J. WUENSCH

Division of Comparative Medicine

FACILITY MANAGEMENT AND ANIMAL CARE

The average daily census of laboratory animals increased approximately 11% in FY90. Mice remain the primary species used by investigators at MIT and represent more than 90% of the animal population. NIH grants totalling \$444,000 for renovations and improvements in the animal facilities were used to install monolithic ceilings in the E17 animal rooms and to begin purchase and installation of new cagewashers and autoclaves in Buildings 56 & E17. Storage space in E18 has been converted to a fully equipped, transgenic surgery suite and a radiology suite is being established in E20. The new Biology building also will have a modern 10,000 GSF animal resource unit under the direction of DCM.

A local area network for 13 PC's at DCM's administrative headquarters has been installed in Bldg. 45. We have acquired specialized software for the DCM's diagnostic laboratory. The package is integrated with DCM's animal facilities software and provides us with time saving data retrieval capabilities as well as automated billing. The automation of the laboratory will help process the 25% increase in diagnostic tests performed this past year. A brochure detailing diagnostic procedures and fees was provided for current and prospective users.

The E25 surgical facility continues to develop as a surgical and veterinary medical resource for investigators using surgical techniques to obtain data. The surgical staff provides consultations to investigators regarding both the technical aspects and medical implications associated with their protocols. The staff provided surgical support for numerous investigators during the past year. Additionally, the DCM surgery facility has been host to several seminars focusing on anesthesia, analgesia and surgical principles.

RESEARCH ACTIVITIES

A competitive renewal for the DCM Diagnostic and Investigative Laboratory was funded for \$2.1 million for years fourteen through nineteen. Funding for year fifteen is 34% greater than the prior year. Our five year NIH postdoctoral training grant is now in its third year of funding. We will have seven postdoctoral trainees this year. During the past year we distributed to all veterinary schools in the U.S. and Canada brochures describing DCM's training program for veterinarians wishing to specialize in laboratory animal medicine. We also continue to provide research guidance to UROP students and serve as advisors for preveterinary undergraduate students.

Research funds for FY91 total \$1.1 million. In addition, DCM has four pending grants submitted to NIH. DCM members were involved as Principal Investigators or Co-Principal Investigators in 11 NIH, NCI or other individual supported research activities. DCM faculty and staff published two chapters, 14 papers and 13 abstracts in FY90. There are currently six papers in press, three accepted for publication and eight papers submitted for publication.

REGULATORY/TRAINING ACTIVITIES

DCM, in conjunction with the Committee for Animal Care, continues to conduct an all day training sessions for principal investigators and their staff. In addition, investigators, research technicians and students were given practical training in various animal handling techniques during FY90 by DCM personnel. The Division's veterinary staff hosted and provided the majority of instruction for the New England Branch AALAS course for animal care technicians during the past year.

James G. Fox

Energy Laboratory

Since 1972, the Energy Laboratory has engaged groups of faculty, students, research staff, and visiting investigators in multidisciplinary research on a wide range of topics related to energy supply, extraction, conversion, and utilization and their impacts on the environment. Professor Jefferson W. Tester assumed full responsibility as director of Energy Laboratory operations in July 1989. Professor David C. White, former director of the Laboratory, continued throughout the year as acting associate director to assist Professor Tester.

Current Laboratory projects emphasize the efficient conversion and clean utilization of fossil fuels, energy efficiency in transportation systems and manufacturing, and the performance of machines and properties of materials used in energy-consuming equipment. New research initiatives have been launched in the areas of renewable resources such as hot dry rock geothermal and biomass energy systems, fuel cells for more efficient energy conversion, remote gas utilization using solid carbides, and energy integration and conservation in the pulp and paper industry. In addition, a major international program in nuclear reactor safety was started this year under the direction of Professor Kent Hansen.

The Laboratory sponsored an international conference on *Energy and the Environment in the 21st Century* to discuss critical issues associated with energy supply and use and their environmental consequences. In addition to providing a forum for exchange of current technical information on energy technology, the conference was structured to review and evaluate future R&D issues and opportunities in the context of minimizing environmental effects by conservation and efficiency improvements and by introducing new energy technology. Professor Tester served as the chair of the organizing committee that included Professors David White, John Heywood, Janos Beer, Adel Sarofim, Kent Hansen, and Leon Glicksman, Dr. Malcom Weiss, David Wood, Howard Herzog, and William Duggan. The conference was held at MIT on March 26-28, 1990, and was attended by more than 600 people. The meeting included more than 70 technical papers and plenary addresses by Senator Albert Gore, Jr.; Richard Morgenstern, Director, Office of Policy Analysis, U.S. Environmental Protection Agency; and MIT President Paul E. Gray. The proceedings will be published as a major book by MIT Press, scheduled for release in the fall of 1990. Following the conference, Laboratory staff were actively involved in reviewing and editing the papers for the final volume.

The Center for Energy Policy Research (CEPR), now organized as a joint center of the Energy Laboratory, the Department of Economics, and the Alfred P. Sloan School of Management, had another very active year: it sponsored three conferences and published 15 working papers and seven major journal articles. CEPR projects are currently organized under five areas: (1) investment, contracting, and finance, (2) international energy markets, (3) energy industry organization and regulation, (4) energy demand, productivity, and economic growth, and (5) technology and policy studies. This year the CEPR sponsored a *Workshop on Risk, Options, and Investment in the Energy Industries* (February 26-27, 1990) and the inaugural conference on *The MIT International Program on Enhanced Nuclear Power Plant Safety* (March 8-9, 1990). In addition, the CEPR is developing a new program on environmental economics, management, and policy that will concentrate on topics closely related to energy production, conversion, and utilization and their environmental impact. Toward this objective, the Center organized a

Workshop on Energy and Environmental Modeling and Policy Analysis (July 31-August 1, 1989) to review and analyze energy and environmental modeling and policy issues, particularly as they relate to global climate change.

The estimated research volume for the Energy Laboratory in FY1990 is \$9.5 million, an increase of about 5 percent from FY1989. The distribution by research area is approximately as follows:

- health and toxicological effects of energy use--14 percent;
- transportation propulsion--12 percent;
- energy engineering and materials--15 percent;
- combustion and fuels research--20 percent;
- energy economics, management, and policy--12 percent;
- electric power equipment and systems--11 percent;
- nuclear systems--8 percent; and
- environmental research--4 percent.

JEFFERSON W. TESTER

Harvard-MIT Division of Health Sciences and Technology

INTRODUCTION

The Harvard-MIT Division of Health Sciences and Technology (HST Division) effectively 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/Medical Physics equips highly qualified engineers and physical scientists for independent research careers working on problems of significance to human health. 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 Division is administered by Roger G. Mark, Matsushita Professor of Electrical Engineering in Medicine at MIT, and Richard J. Kitz, Henry Isaiah Dorr Professor at Harvard Medical School who function as Co-directors. They work intimately with MIT Associate Provost, Kenneth Smith, and Harvard Medical School Executive Dean for Academic Programs, James Adelstein. This academic structure assures close communication and cooperation between the two institutions at the highest administrative levels. Courses are taught by faculty members from both Harvard and MIT and are held on both campuses. HST courses are generally available to undergraduate and graduate students at MIT and Harvard.

ACADEMIC PROGRAMS

A total of 212 graduate students were registered in HST degree programs during the past academic year. One hundred and sixty-seven were MD candidates of whom 66 were simultaneously pursuing PhD degrees. There were 54 students involved in the Doctoral Program in Medical Engineering/Medical Physics. One student was registered for the doctoral degree in Applied Biology in Medicine, and 2 students were enrolled in the Interdepartmental Doctoral Program in Biomedical Engineering.

Thirty-one HST students received the MD degree during this academic year, 6 students received PhD degrees in Medical Engineering/Medical Physics, and 2 students received the interdepartmental doctoral degree in Biomedical Engineering.

The Division introduced two new courses for the first time this year. One is a clinically oriented course which is designed to involve HST/MD students in the long-term care of medically fragile patients with chronic illness who are living in the community. The course, HST-230, Real Medicine, is open to second year students and is intended to be a longitudinal 3-year commitment in which the students will form their own "group practice" imbedded within an existing community-based practice. Issues such as medical decision-making, technology utilization, biomedical ethics, health care organization and financing, home health care, terminal care in community settings, nursing home issues, and medical legal issues will be subjects of study and discussion. The second course addresses the need for advanced courses in biomedical image processing. The new offering is HST-583, Advanced Topics in Image Analysis for Medical Applications, taught by Dr. Justin D. Pearlman. The subject introduces students to advanced methods and concepts for computer analysis of medical image sequences, and contains a substantial laboratory component.

HST and the Nuclear Engineering Department at MIT have been engaged in vigorous dialogue over the past year in order to develop a plan by which the Radiological Sciences Doctoral Program would be made joint with HST. A plan has been approved by both the faculties of Nuclear Engineering and HST, and by the Committee on Graduate School Policy. The degree program will stress a rigorous foundation in fundamental physics, together with added training in the life sciences. Thesis research will take place on the MIT campus, and in the Radiology Departments of the Harvard Teaching Hospitals. The first students have been admitted into the program which will begin formally in the Fall of 1990.

The HST external Advisory Committee visited the Division for the second time in March, 1990. The focus of

their intensive review was the quality of student research. The 16 members of this Committee spent 2 days reviewing the Division's research policies, and conducting in-depth site visits with 25 HST students and their mentors. The Committee reviewed the research of students enrolled in the Medical Engineering/Medical Physics Doctoral Program, MD/PhD Programs, and MD-only Programs. In their report to the Provost at MIT and the Dean at Harvard Medical School, the Committee concluded, "The research conducted by the students in this Program is of excellent quality. Much of it must be among the very best of the graduate research of Harvard or MIT. The Administration can be confident that this research program meets the high standards of two premier institutions." The Committee report also provided a number of constructive suggestions which were discussed in detail by the HST faculty during two spring planning retreats.

FACULTY AND STAFF

Dr. Richard Kitz has indicated his desire to relinquish his administrative responsibilities in HST in order to give his full attention to the demands of the Department of Anesthesia at Massachusetts General Hospital which he heads. The Robert Ebert Professorship of molecular medicine at the Harvard Medical School has been committed to the next Co-director of HST. A search committee has been nominated by the Dean, and has commenced its work. Dr. Walter Abelmann, Professor of Medicine at Harvard Medical School will become the interim Co-director as of September 1, 1990. Dr. Abelmann has been closely associated with the HST Division since its inception, and brings with him an intimate knowledge of its history, policies, and students.

Dr. Glenn Rennels, MD, PhD, resigned his appointment as Cabot Assistant Professor of Artificial Intelligence in Medicine effective July 1, 1990.

The Irving M. London Teaching Award was given to Dr. William M. Kettyle for his excellence in teaching Endocrinology.

Mr. Ronald Smith has joined the staff as special assistant for academic administration. Mr. Smith, formerly Associate Registrar at MIT, will provide leadership in the development of improved policies and procedures for registration and academic record-keeping for all students in the Division, and in interfacing their complex degree programs with the host institutions.

ROGER G. MARK
RICHARD J. KITZ

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. The program is affiliated with the Mineral Resources Program of the Bureau of Mines of the U.S. Department of the Interior. The MMRRI of MIT participates in the research programs of the Generic Mineral Technology Centers for Pyrometallurgy and for Respirable Dust of the Bureau of Mines. It also is 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 U.S. Department of Energy. Personnel of the MMRRI are providing the technical leadership for the plasma arc test facility that is being built at the Charleston, SC, plant of the Macalloy Corporation. This facility is to be employed to evaluate plasma arc methods for smelting ferro-chromium from chromium ores available to American industry; other uses for the facility are being planned. The 1.5 megawatt facility will be placed in operation early in August, 1990, and the test program will be undertaken shortly thereafter. The program is funded by the Strategic Materials Office of the Defense Logistics Agency, and other participants in the program are the South Carolina Research Authority, The Macalloy Corporation, and Clemson University.

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. The funds are used to support two undergraduates in their work in the REMERGENCE (Resource Extraction, Materials and Energy, Reservoir, Geotechnical, ENvironmental, and Construction Engineering) Laboratory and several graduate 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.

John F. Elliott

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 Aeronautical 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. Observatory instrumentation also includes the 18m radio telescope at Westford using 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 250 researchers from US and foreign institutions have used the Observatory instrumentation, including a large number of 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 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 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 summer program for middle school students under the NSF Young Scholars Program.

During the past year, a three-year program to upgrade the 37m radio telescope for operation up to 115 GHz (2.6 mm wavelength) was initiated. This requires active compensation for thermal and gravitational distortion effects on the antenna surface as well as significant improvement in antenna pointing. The first year's work was principally devoted to radio and physical measurements in preparation for the upgrade. Radio holographic maps were made of large scale antenna surface deviations under differing thermal and gravitational conditions to determine the corrections required from a deformable subreflector and thermal control of the splice plate, a solid aluminum section which connects the lighter honeycomb antenna panels. A major physical improvement accomplished was the stabilization of the splice plate by preloading its sections, resulting in a more stable and predictable structure that also better matches the improved antenna structural model produced by our consultants, Simpson, Gumpertz & Heger. Direct physical measurements of the surface panels showed small scale rms surface deviations of 0.13 mm which would be adequate to support the upgrade. Techniques for alignment of the antenna surface were further refined and adjustment tools developed. The azimuth drive gearboxes were refurbished as a part of a long term maintenance program on the antenna, much of the mechanical and hydraulic equipment on the antenna having been in service for over 25 years. New subreflector actuators were also installed on the antenna.

Low noise Superconductor-Insulator-Superconductor (SIS) mixers were obtained from the National Radio Astronomy Observatory, and fabrication of receivers for the 3 mm-wavelength band was initiated. These receivers are cryogenically cooled to liquid helium temperatures and the feeds as well as the receiver front end are contained within the cryogenic vacuum dewar. Fabrication of a new wideband spectrometer is proceeding with the acquisition of high performance correlator integrated circuits and printed circuit boards. This five-channel spectrometer will support up to 746 MHz total bandwidth with a large selection of available bandwidths and resolutions to meet experimental requirements.

*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 York at Stony Brook, Tufts University, University of Massachusetts, University of New Hampshire, and Yale University.

In single-dish radio astronomy, the study of the galactic center source SgrA using a methanol transition at 36.2 GHz has shown excellent agreement with observations of the NH_3 line in that source, while a survey of compact regions of ionized gas has revealed 12 new methanol sources in the 7_0-6_1 A^+ transition at 44 GHz. Monitoring of flare occurrence in the water vapor spectrum of the galaxy NGC 4258 showed continued regular 90-day periodicity with the exception of an unexplained missed occurrence in November-December 1989, while other extragalactic maser sources continue to indicate stable emission.

The Haystack telescope was also used to search for circular polarization in interstellar water masers. Circular polarization arises due to the Zeeman effect, and its measurement can be used to infer magnetic field strengths in the interstellar gas clumps that form the masers. A positive detection has been made in a maser associated with the star-forming region W49, a source for which instrumental effects can be minimized. In a collaborative project with French astronomers, the telescope of the Instituto de Radioastronomia Milimetrica in Spain was used to search for carbon monoxide emission from quasars. Several new objects were detected, the most interesting being a quasar with redshift 0.3, at a distance of nearly one billion light years. This is the most distant object in which molecular gas has been seen, by almost a factor of two.

As part of its VLBI program, Haystack operates the Mark III and IIIA correlators in support of astrophysical and geodetic research. Independent operation of both correlators, utilizing seven shared playback drives, has improved throughput to the point that processing backlog has been largely eliminated. VLBI research highlights during the past year have been driven by arrays of telescopes which included the newly completed Very Long Baseline Array (VLBA) antennas and existing antennas of large collecting area. The short spacing of the VLBA antenna has permitted the stellar winds of O-type supergiants to be studied with VLBI, and the results show that a small fraction of wind electrons (10^{-5} to 10^{-7}) are Fermi-accelerated to GeV energies by shocks within the winds. The 300m Arecibo telescope joined in the Mark III VLBI Network program conducted in March 1990, allowing the detection thresholds to be as faint as 0.5 millijansky, and thus permitted the systematic study of faint radio objects such as extragalactic supernovae and the magnetic activity above the chromospheres of Pre-Main-Sequence T Tauri stars in star-forming regions. The six T Tauri stars successfully detected are believed to resemble the sun, but at an age of 10^6 years. Continuing astrometric VLBI investigations of the multiple star system Algol have established that the K subgiant, not the B dwarf star, is the source of low-level radio emission. Moreover, the same project has now established that the orbital plane of the well-known close binary systems lies roughly perpendicular to the orbit with its triple companion Am star, contrary to predictions. The characterization of Algol's orbit, whose projected major axis is only 4 milliarcsseconds as viewed from the earth, is a significant achievement for the VLBI astrometric technique.

VLBI measurements of the motion of the earth's tectonic plates, of deformation near the plate boundaries, and of changes in the rate of rotation of the whole earth are now routine, with accuracies on the order of one centimeter in baseline length. Among the many activities this past year two achievements stand out. First, following the California Loma Prieta earthquake in October 1989, deployment of the mobile VLBI systems was rescheduled in order to re-measure geodetic locations for three sites in northern California within 100 km of the epicenter. At Fort Ord, about 50 km south of the epicenter, an additional offset of 49 millimeters relative to the average motion of the site over the past five years was observed, but no such offsets were found at San Francisco. These results were available only one week after the event. Second, during the past year, great emphasis has been given to further improvements in the accuracy of the measurements, towards a goal of one millimeter in local horizontal coordinates and less than five millimeters in station height. To meet this goal, new instrumentation and an improved observing strategy were developed at Haystack, and in October 1989 an extended observing session using antennas in Massachusetts, New Mexico, California and Alaska was conducted to test the expected improvements. Over the 20 day period the fourteen observing sessions yielded a position for the Pie Town, NM site with a repeatability of one millimeter in the horizontal and 3 millimeters in the vertical. While this was better than anticipated in the first major program with the new systems, it is not expected to continue when seasonal variations are encountered, but the experiments will provide the data for improving atmospheric, antenna, and earth models.

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 ten 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 Honeywell, and complete VLBA recorders can be obtained from a U. S. company. Haystack has formulated a plan to continue recorder development to provide higher data rates for future enhancement of the sensitivity of the VLBA and other VLBI networks. This was based on a recently-performed laboratory demonstration of recording at a rate of one Gigabit/second.

The Haystack Atmospheric Sciences program has successfully combined observations from the Millstone Hill UHF radar and the co-located optical Fabry-Perot interferometer to expand the data base of upper atmospheric observations at the solar cycle peak. The measurements were aimed at addressing the specific issues of energy and momentum coupling mechanisms between the solar wind and the earth's magnetosphere, ionosphere, thermosphere system. This is part of an NSF-sponsored effort which forms an element of the U. S. Global Change Research Program. Scientific highlights include the determination of neutral winds in the altitude range between 100 km and 130 km at a number of latitudinally spaced sites, and combined radar/optical measurements of neutral atmospheric temperatures at altitudes near 250 km. A multi-pulse technique was used to investigate the phase velocity of unstable plasma waves in the E-region of the ionosphere, and radar/satellite studies addressed the conditions associated with unstable wave growth and enhanced radar backscatter in the topside ionosphere (>500 km). Magnetic storm studies of equatorward surges in the thermospheric neutral wind complemented those directed towards determining the equatorward penetration limit for the storm-enhanced ionospheric electric field. The UHF radar capacitor bank was rebuilt, eliminating all PCBs from the radar system, and the zenith-directed 67m radar antenna was strengthened with new support cables.

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: eight 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 has been renewed for three years with a 50 percent increase in support.

A new major project on in-pile sensors was initiated with support from a Japanese company 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 US research reactors at an expense an order of magnitude larger.

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 US universities.

During the past year our emphasis has been in understanding the origin and evolution of the volcanism that forms chains of volcanoes on the seafloor, e.g. the Hawaiian Islands, in collaboration with Visiting Professor M. O. Garcia (University of Hawaii), and the Ninetyeast Ridge in the Indian Ocean. In early 1990 we initiated a new project, the study of an Upper Mantle Peridotite body exposed in northern Japan. This research will involve a Japanese graduate student at MIT and close collaboration with several Japanese researchers.

During 1989-90 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 Lowell, the University of Maryland, the Land Resource Research Center, Agriculture Canada, Rutgers University, the University of Massachusetts, and Lawrence Livermore National Laboratory. Commercial organizations that utilized the NAA expertise of NRL during the past year were GTE, Waltham and Danvers, Massachusetts; Spire Corp., Massachusetts; Darnes & Moore, Illinois; United Illuminating, Connecticut; and Polaroid Corp., 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. A substance formed during CuO and Y_2O_3 reaction was characterized for Professor M. J. Cima. Impurities that may produce long-lived radioactive products in insulators were identified for the Plasma Fusion Center.

Dr. Olmez has been actively engaged in a number of environmental research projects. Financial support has been obtained from the Environmental Protection Agency (EPA) to investigate the possibility of using rare earth elements as markers for motor vehicle emissions; from Health & Welfare, Canada, on characterization of acid aerosols using micro-orifice impactors; and from the Massachusetts Bay Program to develop a methodology to trace the movement of sewage sludge in Boston Harbor.

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 third 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 in the last three years.

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) and from Dr. Takashi Washio, a visiting engineer from Tohoku University in Japan. 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 seven publications

during the past year. In addition, a major report summarizing both the theoretical and experimental work performed in this area from 1988 to 1990 has been issued. This report complements two earlier ones that covered the years 1983-1986 and 1986-1988, respectively. 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 *a 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 were the incorporation of a stable feedback methodology in the MIT-SNL laws and the extension of the 'reactivity constraint approach' to the control of reactors that are characterized by spatial dynamics. Research in progress includes: 1) the development of methodologies for the control of core average temperature, 2) estimation of the degree of subcriticality of a nuclear reactor, 3) the extension of the non-linear closed-loop control techniques to the operation of various reactor plant components such as steam generators, 4) causal analysis, and 5) continued work to improve the robustness of the control laws used for the rapid maneuvering of a reactor's neutronic power. One B.S., two M.S., 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 three 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 supported by the Empire State Electric Energy Research Corporation (ESEERCO) and the Electric Power Research Institute (EPRI). Funding at the level of \$2.5 million for four years 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) and Professor Michael J. Driscoll (NED). Others already participating are Dr. Gordon Kohse and 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 from the Japanese government through the Nuclear Power Engineering Center (NUPEC). This new project is funded for four years.

IRRADIATION-ASSISTED STRESS CORROSION CRACKING

A new 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 is supported at the \$500,000/year level and will address 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.

SENSOR PROJECT

The Sensor project is a new 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 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) production of Pt-197 and Os-193 Mössbauer sources for the Chemistry Department at Northeastern University to study the chemistry and structure of gold compounds, particularly those exhibiting anti-arthritis and anti-tumor activity; 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 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. William Carter of American Superconductor Corporation used fast neutron irradiation in an unsuccessful attempt to increase the critical field and critical temperature of their new high temperature superconductor material; 4) Dr. J. R. Thompson, Oak Ridge National Laboratory, conducted similar irradiations to study ORNLs high temperature superconducting materials; 5) Kevlar/epoxy composite materials, with potential application as an insulator for fusion device magnets, were irradiated and measured for radiation damage effects by Dr. Ronald L. Alfred of PDA Engineering; 6) Dr. Leonard T. Summers of Lawrence Livermore Laboratory irradiated similar Kevlar/epoxy composites to determine their impurity content for estimating radiation dose levels to be expected from fusion devices; 7) Drs. Robert F. Anderson and Alan P. Fleer of Woods Hole Oceanographic Institute used irradiation to determine natural actinides and plutonium in marine sediments; 8) R/A Services Company and Gulf Nuclear each purchased from us about one curie of radioactive scandium-46 for use in oil-well logging; 9) Drs. Joseph D. Zuckerman and Marco Chinol of Mt. Sinai Hospital purchased holmium-166 for use in arthritis treatment research; and 10) 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 687

students and 179 faculty and staff from over 47 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 US; 2) analysis of sediments by neutron activation for Woods Hole Oceanographic Institute; 3) neutron activation analyses of ice cores for the State University of New York, Buffalo; 4) intercomparison studies for Land Resources Research Center, Canada; 5) gamma irradiation of plant seeds for several area high school students participating in science fair projects; 6) ongoing research to identify elements other than lead from motor vehicle emissions in collaboration with Professor G. E. Gordon, University of Maryland; 7) food, water, and soil analysis from Rota Island, Forsyth Dental Center; 8) measurements of boron concentration and work on high resolution track etch autoradiography were performed for Professor Robert Zamenhof of Tufts-New England Medical Center; 9) neutron activation analysis of water specimens by Professor Jack Beal of Fairfield College; 10) radiation hardness measurements of drift tube detectors being developed for the Superconducting Super Collider program by Professor James Rohlf of Boston University; 11) gamma-ray spectroscopy of pure elements from NASA, Long Duration Exposure Facility; and 12) 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, Mechanical Engineering Department, Nuclear Engineering I, Course NE 2541, 15 students, 3 visits; 2) Northeastern University, Physics Department, Course PHY 1555, 5 students, 2 visits; 3) the University of Massachusetts, Harbor Campus, Professor Martin Posner, Department of Physics, Physics 603, 24 students, 6 visits; and 4) Bates College, Department of Physics, Professor John Smedley, 12 students, 2 visits.

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. Seven seminars of four and one-half hours each were held in the fall (4 classes) and spring (3 classes). The attendance increased significantly this year to 86 teachers and 79 students.

MIT RESEARCH REACTOR

The MIT Reactor completed its 32nd year of operation, its 16th 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 August through November 1989 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 65 hours per week with 49 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 254,950 megawatt-hours at June 30, 1990. The MITR-I generated 250,445 MWH 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 US 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 981. There were 143 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 1562 people toured the MIT Research Reactor during 1989.

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 US 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 37th year of continuous operation in 1989-90. The year was marked, on the one hand, by the continued success of the Center's educational programs coupled with a significant increase in its research activities and, on the other, by continued planning for future development.

Highlights of the year included: submission of a proposal to the Institute's Administration, endorsed by 39 faculty and senior research staff, to establish a Center for Decision Sciences at MIT; preliminary approval of the proposal by the Administration and allocation of funding for developmental activities toward establishing the Center; continuing excellence of our academic programs and the largest applicant pool in the history of the ORC; a wide variety of methodological and applied research projects and an increased research volume at the ORC; and a number of individual distinctions for our students and affiliated faculty and staff. This report provides some details on these 1989-90 activities and reviews briefly the ORC and its educational and research programs.

FACULTY AND STUDENTS

Professor Steven R. Lerman (Civil Engineering) became affiliated with the ORC this year, while three faculty and senior staff resigned from MIT, bringing the total number to 31. 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. Marcia V. Chapman served as the Assistant Director and Paulette P. Chiles 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 1989-90, these programs enrolled 52 students--34 PhD candidates and 18 SM candidates. It conferred nine master's degrees and six PhDs in operations research. Several other PhD theses were in the final stages of completion in the summer of 1990, and three more PhD degrees will be awarded by September 1990.

For the Fall Term 1990, the ORC expects an incoming class of 13 students. Eight of these new students are foreign (from seven different countries) and six are women. They were carefully selected from one of the largest and most outstanding pools of applicants in memory. As an example, 29 of this year's applicants had a 790 or 800 score (out of a maximum of 800) in the quantitative portion of the Graduate Record Examination and another 20 had scores above 750. We had an applicant pool of over 90 individuals, a 25 percent increase over previous years.

ACADEMIC PROGRAMS

The ORC's academic programs continue to be recognized as ranking among the very best nationally and internationally. This year we had the largest pool of applicants for admission in our history, while interest in our students from prospective employers remained strong.

In view of constraints due to 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.

Throughout the academic year, we have also discussed extensively with our faculty and students the structure of our qualifying and general examinations. A number of changes will be instituted during 1990-91 as a result, while the process of reviewing our curriculum and examination structure will continue.

RESEARCH ACTIVITIES

During 1989-90, the volume of research conducted directly through the ORC grew significantly. 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 for integer programming, projective transformation methods for linear programming, polytopes, and cluster analysis; parallel and distributed computation and algorithms; network optimization and network design with an emphasis on the development of extremely efficient algorithms for solving classical problems; 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; and industrial production and transportation logistics.

Several organizations sponsored research projects at the ORC during 1989-90, 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 1989.

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 the Campbell Soup Company. 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.

ORC faculty, in cooperation with the Center for Transportation Studies, presented in April 1990 a one-and-a-half day symposium on "Advances in Mathematical Optimization." Seven ORC faculty and alumni gave presentations on topics that reflect the cutting edge of current research on applications of mathematical programming. Approximately 40 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 George B. Dantzig, from the Department of Operations Research, Stanford University; Ward Whitt, from AT&T Bell Laboratories; Eric Wolman, from Michigan Cancer Foundation and AT&T Bell Laboratories (retired); Alexander Rinnooy Kan, from Econometric Institute, Erasmus University and The Wharton School, University of Pennsylvania; and J. Michael Harrison, Graduate School of Business, Stanford University.

DECISION SCIENCES CENTER

Following a three-year period of discussion among faculty and staff, a detailed proposal was prepared to establish a Center for Decision Sciences (CDS) at MIT. This proposal, endorsed by 39 faculty and senior researchers from all five Schools of the Institute was submitted to the MIT Administration in October 1989. It calls for a phased development of a Center that would include: a three-track master's and PhD program in Operations Research, in Statistics and in Decision Processes; a major research program centered on the decision sciences and technologies in the era of the "information revolution;" a computational laboratory; a learning laboratory; a large industrial affiliates program; and a visitors and senior fellowships program.

The MIT Administration has responded favorably to this proposal and has made available \$50,000 through the Sloan Fund to support activities aimed at funding and developing the Center during 1990-91. Professor Thomas L. Magnanti, Codirector of the ORC, will return from his sabbatical leave in September 1990 and will assume the leadership and coordination of these activities.

SOME INDIVIDUAL ACCOMPLISHMENTS

A number of ORC-affiliated faculty and staff received noteworthy awards or "made the news" during 1989-90. We mention a few examples below:

Professor Lawrence M. Wein (School of Management) won an NSF Presidential Young Investigator (PYI) Award. He joins Professors James B. Orlin (Management), John N. Tsitsiklis (Electrical Engineering and Computer Science), and David Shmoys (Mathematics - now at Cornell), ORC faculty who previously received this award. Several ORC alumni are also PYI Award holders: Daniel Bienstock, currently in the Department of Industrial Engineering and Operations Research at Columbia University; and Cynthia Barnhart (Civil Engineering, TSD), currently in the Department of Industrial and Systems Engineering at Georgia Tech.

This year's George E. Nicholson student paper competition of the Operations Research Society of America (ORSA) recognized three current and former ORC students out of the five finalists for the prize. Michel Goemans (thesis supervised by Dimitris Bertsimas) received second prize. Leslie Hall, now at Princeton (thesis supervised by David Shmoys and Tom Magnanti) and Garrett van Ryzin (D. Bertsimas, supervisor) both received honorable mentions. Dimitris Bertsimas, formerly an ORC student and currently an ORC faculty member (School of Management) won the ORSA Dissertation Prize in Transportation Science (Amedeo Odoni, supervisor).

Finally, 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 served as Editors or Area/Department Editors of the top professional journals in OR and management science.

THOMAS L. MAGNANTI
AMEDEO R. ODONI
Codirectors

Plasma Fusion Center

The overall 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 tokamak), (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 (c) a broad program of technology and engineering development (e.g., magnet systems, superconducting materials development, fusion environmental and safety studies, advanced millimeter-wave source development, and system studies of fusion reactor design, operation, and technology requirements).

The Plasma Fusion Center technical programs are supported principally by the Department of Energy's Office of Fusion Energy. There are approximately 300 personnel associated with PFC research activities. These include: 35 faculty and senior academic staff, 72 graduate students and 28 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 19 visiting scientists; 32 technical support personnel; and 35 administrative and support staff.

One of the highlights of the past year has been the emergence of an active K-12 educational outreach program, through which we have attempted to convey the excitement of our field, and more generally, the rewards of being a professional scientist or engineer, to students mainly at the high school level. Our outreach program is multifaceted, but one of our most successful recent efforts was the hosting of a high-school outreach day in which over 90 high-school teachers and students from across the state visited the PFC and learned first-hand about our work. Our outreach activities are continuing and will be expanded during the coming year. Our goal is to make a contribution, however modest, to reversing the deplorable decline in scientific literacy which is so painfully evident and pervasive throughout our culture.

Over the past decade, funding for fusion research has been in a continuous state of decline, as development of new energy sources has had a very low priority on the nation's domestic agenda. As a result, it has been difficult both at MIT and at other fusion laboratories to maintain momentum in fusion research and to develop a long-range plan for fusion development which was not prematurely rendered inoperative by precipitous and unexpected decreases in funding levels. Fortunately, the substantial investments in fusion facilities which occurred after the oil embargo of the mid-1970's, have nevertheless been rewarded with striking technical success, as the largest fusion machines, namely the TFTR device at Princeton and JET in Europe, have recently produced plasma conditions (density, temperature and confinement time) approximating those required for fusion energy breakeven. We fully expect this progress to be mirrored in the Alcator C-MOD device, now in the final stages of construction and scheduled for operation in early 1991 at the PFC.

Two actions initiated during the past year by the Department of Energy have suggested that a more stable and predictable path for fusion development may soon be available. The first is the formulation of a National Energy Strategy, a planning document which will be used to guide the development of energy options for the U.S. into the early part of the century. Fusion appears in draft versions of this document as an appropriately long-term and desirable energy option. The second is the formation of a Fusion Policy Advisory Committee (FPAC), whose purpose is to recommend to the Secretary of Energy an optimal way of structuring the nation's fusion program. The FPAC has prepared an interim report that recommends aggressive development of fusion energy, including near term commitment to key developmental steps such as a burning plasma experiment and construction of an engineering test reactor through an international partnership. The strong endorsement that FPAC is giving to fusion's role as an environmentally attractive energy source, together with its approbation of the excellent technical progress made in the last several years, is extremely gratifying. The FPAC report should set the stage for a more aggressive fusion program, one that could lead to the realization of fusion's potential beginning in the early part of the next century. An important consequence for the PFC would be a strengthening of several programs which have been severely

weakened by years of declining DOE fusion budgets. With this as background, we now review highlights from selected research efforts presently underway at the PFC.

ALCATOR CONFINEMENT EXPERIMENTS

The primary objective of the Alcator experimental program is to develop the basic physics understanding of the stability, transport, and radiation properties of high-temperature tokamak plasmas at near-reactor conditions and to develop radio-frequency (RF) methods for heating and driving currents in plasmas at thermonuclear temperatures.

The major confinement activities at the Plasma Fusion Center now focus on the design, construction and preparation of the new tokamak facility, Alcator C-MOD, which is sited in the east wing of the Nabisco Laboratory. Alcator C-MOD will provide valuable technical information regarding the operation of the high-field ignition experiment, CIT, and contribute to the advancement of tokamak concepts and physics understanding in areas such as ohmic- and auxiliary-heated confinement, stability, divertor-edge plasma behavior, control of plasma shape and profiles, and non-inductive current drive. The Alcator program is under the direction of Professor Ian H. Hutchinson, the Toroidal Confinement Division head. Its activities are organized into four groups. The 'Plasma' group, headed by Dr. Stephen M. Wolfe focuses on the planning and analysis of the experimental program, with special interests in the areas of MHD (Robert Granetz) and Transport (Martin Greenwald). Computing and data-acquisition also come under this group. The 'Experiment' group's activities, under Dr. Earl Marmor, lean more toward implementation of the experimental tasks, with responsibility for diagnostic development and coordination (James Irby). The edge plasma activities (Bruce Lipschultz) are also in this group. The RF heating group, under Professor Miklos Porkolab, has primary responsibility for the implementation and analysis of the ion cyclotron heating on the tokamak. The Operations group, headed by David Gwinn, has been responsible for the fabrication phase and now takes over the day to day operation of the facility. The project engineering (Stephen Fairfax) is in this group.

Alcator C-MOD: The successes of the Alcator A and C tokamaks have demonstrated the value of the high-field, high-density, compact tokamak approach to plasma confinement. This approach is now embodied in the proposed national experiment, the Compact Ignition Tokamak (CIT), which offers the most promising and cost-effective means to explore fundamental physics issues associated with burning fusion plasmas. However, the step from Alcator C to CIT constitutes a large extrapolation in size, power, current, and other parameters. Therefore Alcator C-MOD provides a prudent and cost-effective way to develop an understanding at intermediate plasma conditions. It satisfies the need for further physics research on an experimental scale short of that required for fully ignited plasmas. The flexibility inherent in a moderate-scale facility can be used to explore different options and possibilities which the (necessarily) less flexible ignition experiment cannot explore.

In addition to its role as a prototype for CIT, Alcator C-MOD represents the next logical step in the high-field tokamak approach. Unlike its predecessor, Alcator C, it incorporates several modern tokamak features, such as a shaped, non-circular plasma cross-section, a poloidal divertor, and dominant auxiliary heating. These features will allow the investigation of high-density, high-temperature, ion- and electron-cyclotron-heated plasmas, with the goal of understanding the physics of RF heating, confinement, stability, impurity control, and fueling and shaping of high-performance tokamaks. Final approval for the construction of Alcator C-MOD was received in April 1987, and initial experimental operation is now scheduled for early 1991.

The major radius of the Alcator C-MOD plasma will be approximately 67 cm (similar to Alcator C), and its minor midplane radius will be 21 cm. The plasma half-height will be up to 40 cm, with a typical elongation of 1.8. The toroidal field of 9 T is somewhat less than that in Alcator C, but the advanced shaping permits greatly increased plasma current, up to about 3 MA. Various innovative engineering features are incorporated in the design. The toroidal field magnet has sliding joints in its discrete coils; these permit the poloidal field coils to be mounted inside the toroidal field coils. The joints also reduce peak stresses in the magnets, transferring them to a massive, steel supporting structure that surrounds the machine. This design allows greatly improved access to the plasma for heating, diagnostics, and maintenance.

During the past year, good progress has been made in the construction of the Alcator C-MOD facility. Essentially all of the hardware costs have now been committed for component fabrication by various industries. Major items include: \$1 million for the toroidal field magnets (Mitsubishi, Japan), \$0.3 million for the vacuum vessel (Meyer Tool, Illinois), \$1.8 million for the support structure (Thyssen, Federal Republic of Germany; Ladish, Wisconsin; Southern Bolt, Louisiana), \$1.6 million for the main power supplies (Robicon Corporation, Pennsylvania), \$0.2 million for RF power-supply modification (Uptegraff, Pennsylvania; Varian, Massachusetts), \$0.5 million for molybdenum tiles (Climax Specialty Metals, Connecticut), \$2.6 million for site modification and cell construction in the east wing of the Nabisco Laboratory (Vappi & Co., Cambridge), and \$1.1 million of MIT funds for the development of laboratory

support space in the central section of the Nabisco Laboratory (Vappi & Co., Cambridge). The last two items represent a major improvement of the Nabisco Laboratory site for experimental plasma physics research.

The forged magnet superstructure has been delivered and a test assembly successfully completed. The lower part of the structure is now installed on its support legs in the experimental cell. The vacuum vessel has been delivered and tested, and a trial fit of the vessel into the superstructure has been completed as has the installation of the internal magnetic diagnostics. The core of the toroidal field magnet and half of the outer sections have been delivered. The ohmic heating transformer has been wound on the core and the other poloidal field magnets are wound and under preparation for epoxy impregnation. The toroidal field power supplies have been delivered and are completing installation. The remainder of the converters will be delivered during the next three months. Preparations for the flywheel to be added to the alternator for extra stored energy are proceeding. Completion of the entire tokamak assembly and obtaining first plasmas is scheduled for February 1991.

Progress is continuing within the Alcator base program in the scientific preparation for experiments. This includes the detailed design and optimization of experimental plasma components such as divertors, first-wall components, and RF-wave launchers. A major effort is devoted to the development and implementation of diagnostics for determining fundamental plasma properties. These include diagnostics that will be used routinely for plasma-feedback control (a major technical challenge), as well as state-of-the-art diagnostics to provide detailed measurements. An example of the latter is a repetitive, spatially-scanning Thomson scattering system, developed in collaboration with Science Research Laboratory, Inc. which will permit 2-D profiles of density and temperature to be obtained during each discharge. The advanced diagnostic set planned for Alcator C-MOD will allow a fuller description of plasma behavior and hence improve the predictive understanding of the fundamental properties of magnetically confined plasmas.

Graduate student involvement in the various aspects of the Alcator scientific program is extensive and diverse. Students are conducting thesis research and working as research assistants in areas such as: optimized plasma control, cryogenic hydrogen pellet injector development, diagnostic design, and magnet materials analysis.

Collaborative Programs: While Alcator C-MOD has been under construction, several of the scientific staff have been involved in experiments at other facilities. Funding from the Department of Energy, as well as other sources, has been available for this purpose, and the participation of experienced research staff in the wider international fusion program has been very productive. These collaborations help to establish good international relations as well as enhance the experience and productivity of the scientific staff.

Two C-MOD subsystems are being built in collaboration with fusion groups in the US and abroad. A hybrid computer for control of plasma position and shape continues to be jointly developed by the PFC and the Centre de Recherches en Physique des Plasmas (CRPP) of the École Polytechnique Fédérale de Lausanne. The CRPP has primary responsibility for hardware and the PFC for software. At the CRPP the computer will be used for plasma control for their TCV tokamak device. Software for data acquisition and analysis is being written, under PFC direction, by groups from the PFC, the Los Alamos National Laboratory (LANL) and the Istituto Gas Ionizzati (IGI) in Padua, Italy. This software, called MDS+, organizes all components of experimental data into a single coherent, hierarchical structure. LANL and IGI will employ the software for data from their reversed field pinch experiments, ZT-H and RFX respectively. The CRPP will also use the MDS+ software.

A particular effort in which the Plasma Fusion Center has played the lead role is in experiments using an impurity pellet injector on the Tokamak Fusion Test Reactor (TFTR) facility at Princeton Plasma Physics Laboratory (PPPL) (Earl Marmor and James Terry). The main diagnostic application of the experiment is to measure internal magnetic field, and therefore q and current density profiles in the plasma. Other applications include the study of electron and impurity particle transport, thermal transport, pellet fueling and pellet ablation physics. The experiment became operational in August, 1989. Since that time, a number of important results have come out of this collaboration. Measurements of internal field profiles have been made for a variety of TFTR regimes, including ohmic, L-mode and in high β_p discharges. Both lithium and carbon pellets have been used to perturb the density, temperature and impurity profiles, and studies aimed at understanding the ensuing transport are underway.

Scientists from the Confinement Experiments Division have participated in various capacities in the national CIT program. PFC researchers have made important contributions in the areas of RF-heating, alpha-particle physics, edge physics, ECH source development, and control systems. Scientists have also participated in various national workshops that have served to define and develop the CIT objectives and predicted performance. Looking further to the future, there is also increased scientific participation in the alpha-particle physics and RF-heating and current drive in the International Thermonuclear Experimental Reactor (ITER) design activity. This effort, which is a quadrupartite collaboration between the US, Europe, Japan, and the USSR, is expected to culminate in the joint

construction and operation of the first fusion engineering test reactor, a large tokamak facility designed to produce 1-2 GW of thermonuclear fusion power when it operates sometime near the middle of the next decade.

APPLIED PLASMA PHYSICS RESEARCH

The primary objective of the Plasma Fusion Center Applied Plasma Physics Research Division, headed by Ronald Davidson, is to develop a basic experimental and theoretical understanding of plasma properties. Present applied plasma physics research activities include: experimental research on the Versator II tokamak (Miklos Porkolab and Stanley Luckhardt); construction of the Versatile Toroidal Facility, which will be initially used for simulation of ionospheric plasma phenomena (Marcel Gaudreau, Min-Chang Lee, Stanley Luckhardt, Ronald Parker); collaboration on the PBX-M tokamak at Princeton Plasma Physics Laboratory (Stanley Luckhardt and Jay Kesner); experimental research on electron cyclotron resonance sources and plasma-materials interaction (Donna Smatlak and Barton Lane); fusion theory and computations (Abraham Bers, Bruno Coppi, Thomas Dupree, Jeffrey Freidberg, Jay Kesner, Kim Molvig, Jesus Ramos, and Dieter Sigmar); theoretical research on nonneutral plasmas and coherent electromagnetic wave generation (Ronald Davidson and Jonathan Wurtele); experimental and theoretical research on chaos and the onset of turbulence (Paul Linsay and George Johnston); ionospheric plasma research (Min-Chang Lee); and space plasma research (Ronald Davidson and James Sullivan).

Highlights of progress made during the past year in selected applied plasma physics research areas is summarized below.

Versator Research Program: Versator-II is a medium-sized research tokamak (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 heating and current drive. Experiments on Versator II during the past year have focused on completing Ph.D. thesis projects, including studies of (a) innovative dielectric-loaded waveguide-array couplers for launching "fast-branch" lower-hybrid waves at frequency $f = 800$ MHz, (b) electron cyclotron heating and plasma start-up experiments using a gyrotron microwave source at frequency $f = 35$ GHz, and power up to 100 kW, and (c) studies of plasmas with high values of poloidal beta which may have entered the "second-stability" regime for the first time on any tokamak.

The Versator II facility is also being used in a number of collaborative experiments involving (a) studies of electron cyclotron resonance (ECR) plasma discharge cleaning in collaboration with Alcator C-MOD researchers, (b) antenna development experiments for fast magnetosonic wave excitation in the ion cyclotron range of frequencies in collaboration with Alcator C-MOD researchers, (c) development of an electron cyclotron transmission measurement to probe non-Maxwellian electron populations, in collaboration with the University of Maryland, and (d) studies of plasma turbulence using a reciprocating Langmuir probe apparatus, in collaboration with the University of Texas.

Construction of a new toroidal plasma facility called the Versatile Toroidal Facility (VTF) is underway at the PFC Nabisco Laboratory. VTF is a flexible toroidal facility with the capability of operating with pulsed tokamak discharges of 100-200 ms duration, and with 60-120 s duration plasmas using electron cyclotron resonance (ECR) plasma heating. The physical characteristics of the device are: major radius $R = 93$ cm, minor radius $a = 27$ cm, elongation 1-1.6, and toroidal magnetic field $B = 1.0$ -1.6 T. The ECR plasma capability uses microwave power to heat and sustain a low temperature plasma in a toroidal magnetic field. The ECR plasmas produced in this manner provide an excellent environment for basic plasma studies. Fundamental plasma studies simulating ionospheric plasma processes have recently been funded and will be investigated on VTF by Dr. Min-Chang Lee and co-workers. In addition, a proposal has been submitted to the Department of Energy requesting resources for VTF tokamak operations and non-inductive current drive experiments.

Collaboration on the PBX-M Tokamak: A new series of lower-hybrid current drive experiments is being planned in a collaboration between the Plasma Fusion Center and the Princeton Plasma Physics Laboratory (PPPL). These experiments will be carried out using the PBX-M tokamak facility at PPPL, and represent a continuation of the high-poloidal-beta plasma experiments that were initiated on the Versator II tokamak. The collaboration will investigate the influence of RF-induced changes in the plasma current density profile which are predicted theoretically to improve the stability of tokamak plasmas. Successful current profile control and plasma mode stabilization would have important implications for future fusion reactors. Planning for these experiments has been completed, and it is anticipated that experiments will begin in October, 1990.

Plasma-Materials Interaction: During the past year, work has continued on the frequency scaling studies of highly charged ion production in electron cyclotron resonance (ECR) ion sources. The research has been carried out at 14 GHz and 18 GHz in collaboration with Spire Corporation on the VMX facility, which is the end cell of the former TARA tandem mirror. This work will resume this summer with emphasis on instability studies. The Constance B program was terminated during the past year, and the machine has been disassembled and placed in storage.

With the recent formation of the plasma-materials interaction group, a new area of research has been initiated at the Plasma Fusion Center. This group concentrates on studies of plasma physics issues for semiconductor plasma processing applications. A novel ECR etching reactor concept, the toroidal electron cyclotron resonance reactor, or TECR, was invented in collaboration with Professor Herbert Sawin (Department of Chemical Engineering). This design represents a major improvement in the state-of-the-art axial ECR etcher and promises to reduce greatly the ultraviolet damage to semiconductor wafers and to allow uniform processing over 8-inch wafers. Plans are being developed to construct a proof-of-principle device. Funding has been obtained from IBM-East Fishkill for studies to improve axial ECR reactors based on experimental work done with limiters by the PFC team.

Plasma characterization studies of a microwave-produced, downstream plasma have been carried out using a downstream reactor donated by industry. These plasma and radical sources are used for dry photoresist stripping of semiconductor wafers. The next step in this research involves studies of the sources of damage to wafers in the stripping process. This work will be carried out in collaboration with Dr. Edward Gleason at MIT Lincoln Laboratories.

Fusion theory and computations: The fusion theory and computations group has broadened its range of research, particularly in the area of fundamental and applied plasma turbulence and its relation to fusion plasma confinement. A special one-semester course in plasma turbulence was offered for the first time which was attended not only by students and plasma theorists at the PFC, but also by experimentalists and faculty. Subsequently, a new research project was started on the synergistic effects of (neo)classical impurity accumulation and its impact on anomalous transport due to rippling modes in the plasma edge region, and the bifurcation to the enhanced confinement regime of tokamaks.

Other major topics which have received substantial resources in scientific manpower and international recognition include: theoretical investigations of the physics of plasmas with fusion burn; discovery of the theoretical reasons for the observed plasma pressure (Troyon) limit, and further development of a potentially far-reaching plasma operation mode in the "second-stability" regime; investigations of radio frequency (RF) heating of toroidal plasmas, including transition to stochastic charged particle guiding center motion above a certain RF amplitude, and application of short intense heating pulses of lower hybrid waves including the effects of parametric instabilities; and application of relevant theoretical results to the Compact Ignition Tokamak (CIT) and the International Thermonuclear Experimental Reactor (ITER) design activities through participation in the respective design teams.

Nonneutral Plasmas and Coherent Electromagnetic Wave Generation: A vigorous theoretical program has been carried out during the past year which investigates collective and nonlinear processes in nonneutral plasmas and coherent sources of electromagnetic radiation, such as free electron lasers, cyclotron masers, and relativistic magnetrons. Recent theoretical studies have included: (a) the development of a self-consistent analytical model which describes large-amplitude coherent structures in nonneutral plasmas with circulating electron flow; (b) completion of a major new graduate-level treatise by Professor Ronald Davidson entitled Physics of Nonneutral Plasmas (Addison Wesley, 1990); (c) investigations of the onset of chaos in the particle trajectories in free electron lasers induced by self-field effects and transverse spatial inhomogeneities in the wiggler magnetic field, and (d) analytical and numerical studies of the linear and nonlinear evolution of the sideband instability in a helical wiggler free electron laser using both kinetic and single-particle models to describe the trapped electron dynamics.

Chaos and the Onset of Turbulence: A program of experimental and theoretical research to study systems of coupled nonlinear oscillators has been initiated. The investigation of two or three coupled oscillators which model the van der Pol-Duffing equation is important for developing a detailed understanding of high-power magnetrons and free electron lasers. Experimental work has begun using a modification of some recently finished experiments on coupled oscillators. Correct operation of the apparatus with a single driven van der Pol oscillator has been confirmed by comparing experimental and theoretical results.

An understanding of many coupled nonlinear oscillators is important for models of pattern formation and turbulence in fluids such as plasmas. An array of 256 oscillators is under construction for this experiment. At present, experiments are being carried out with 15 oscillators which are configured so that all oscillators couple equally with each other (so-called "global coupling"). Several phenomena have been discovered which were unexpected theoretically. The distribution of phase locking times is exponential when the oscillators are started with random initial conditions. The number of final states accessible to the locked oscillators increases exponentially with the number of oscillators coupled together. For certain specific initial conditions and coupling strengths, the coupled oscillators phase lock and oscillate with a frequency which is ten times greater than the base frequency. Theoretical work is underway to understand these results, and design of the array of 256 oscillators is being carried out.

Space Plasma Research: During the past year, research has continued on the development of experimental concepts and superconducting magnet designs for both the Astronomy Magnet (ASTROMAG) facility for Space Station

Freedom and the upgraded balloon-borne magnet facility (BBMF). Experiments on these facilities will address mainly problems in cosmic ray astrophysics. One class of experiments will investigate fundamental space plasma processes in the "magnetosphere" of a magnetic obstacle moving rapidly through the ionosphere. Design work has proceeded on a precursor experiment using a small magnet on a sounding rocket with a deployable diagnostics package. Also, during the past year, research has continued on the development of experimental concepts and designs for a laser-radar dust/particulate detection system to be used either in low Earth orbit or on the surface of Mars, and the development of designs for a neutral- and ion analyzer intended as a Titan aeronomy instrument on the Cassini mission to Saturn.

Ionospheric Plasma Physics: Coordinated space and ground-based ionospheric plasma heating experiments have been conducted at Arecibo, Puerto Rico, since December 17, 1989, under the joint U.S.-Soviet Active Space Plasma Physics Program. The very-low-frequency (VLF) waves transmitted from the Soviet ACTIVE satellite interacted nonlinearly with ionospheric plasmas, giving rise to intense radar echoes recorded on the ground. The VLF wave-triggered precipitation of energetic particles from the radiation belts was also observed. The results will be reported at the joint U.S.-U.S.S.R. Workshop to be held in Moscow in 1990.

The construction of the Versatile Toroidal Facility (VTF) at the PFC Nabisco Laboratory is near completion. This is a student-oriented project, involving five graduate students and twenty undergraduate students. The students are currently assisting with the installation of diagnostics. It is estimated that first plasmas will be generated in August, 1990. The VTF facility will be used to investigate nonlinear wave propagation and interaction with magnetoplasmas in a research program cosponsored by the Air Force Office of Scientific Research (AFOSR), the Air Force Geophysics Laboratory (AFGL), the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF). The laboratory experiments are aimed at simulating space plasma phenomena and crosschecking results obtained from field experiments.

FUSION TECHNOLOGY AND ENGINEERING

The Plasma Fusion Center's Fusion Technology and Engineering Division, headed by Bruce Montgomery, provides critical engineering analysis for advanced design projects, and develops advanced superconducting and high-field copper magnet technology for the national fusion program. The areas of research during 1989-90 include: engineering design support for the Alcator C-MOD tokamak (Bruce Montgomery); studies of advanced poloidal field magnets for the Compact Ignition Tokamak (Richard Thome); studies of advanced magnetics for the International Thermonuclear Experimental Reactor program (Joel Schultz); concept development for improved magnetic divertors for tokamak and next-generation test reactors (Tien-Fang (Ted) Yang); development of internally-cooled, cabled superconductors for use in advanced fusion devices (Mitchell Hoenig); basic research on high-field, ductile superconductors (Simon Foner); and advanced magnet and conductor design in support of MHD and high energy physics projects (Peter Marston). Recent progress in selected technology and engineering areas is summarized below.

The Compact Ignition Tokamak (CIT) is proposed as a national project, to be completed in 1997, and to be located at the Princeton Plasma Physics Laboratory. The purpose is to explore and understand the physics of self-heated or "burning" plasmas, while demonstrating 100 MW or more of net fusion power. It will be a copper, high-field ignition device patterned after the Alcator series at MIT. In the engineering area, Bruce Montgomery is serving as Tokamak Systems Engineer, and Richard Thome is manager for the poloidal field system. The CIT will require high strength copper alloy plates for fabrication of the central solenoid and toroidal field coils. Determination of the mechanical properties of these alloys are being developed as a PFC program, with the help of Professors Frank McClintock and Regis Pelloux.

The International Thermonuclear Experimental Reactor (ITER) is a design and R&D activity which has grown out of a US/Soviet initiative at the Geneva Summit. The European Community and Japan are also participating in this three-year design and R&D effort. MIT is responsible for the U.S. poloidal field design, an activity which builds on the PFC's unique expertise gained in the ICCS conductor development program. It is hoped that the ITER effort will result in the decision to proceed with the construction of an international fusion test reactor during the 1990's.

The divertor development group has been active in developing innovative designs for particle control, modular tokamaks and magnetic systems. A novel system to actively recycle plasma ions back into the plasma core from the boundary by a set of ripple coils below the plasma column has been tested on the TEXT tokamak at the University of Texas. The method would induce an influx of circulating particles which could reduce impurity generation and enhance beam heating.

The principal task involving the use of internally-cooled, cabled superconductors (ICCS) is the development of conductors for the two-meter outer-diameter prototype of the central solenoid (ohmic heating) coil for ITER. This task is multifaceted. It involves several collaborative efforts including: conductor sheath development in

conjunction with Professor Ronald Ballinger; the development of a reliable commercial Nb₃Sn superconductor with US wire vendors, including research to develop optimized low-AC-loss conductor in quantities suitable for ITER use; and a joint program with the Naka Fusion Research Institute of the Japanese Atomic Energy Research Institute (JAERI) that will allow testing of a prototype double-pancake coil, starting in October, 1990.

Basic research on high-field Nb₃Sn and Nb-Al superconductors using powder metallurgical techniques has continued. Focus has been on small-scale hydrostatic extrusion processing and on extending practical processing technologies. Exploration of mechanical alloying and rapid quenching has been continued for Nb-Al. Considerable activity has continued during 1989-90 in collaboration with several research groups, evaluating the high-temperature superconductors. DC fields up to 30 T, and pulsed fields up to 60 T are used for characterization.

The principal goal of MHD magnet design has been the development of a high-current conductor for large-scale MHD magnets based on the ICCS design. Conceptual designs of space-based magnet systems for both linear and disk multimegawatt MHD generators have also been developed. Work is also underway for the Superconducting Supercollider on the design and test of an optimized superconducting interconnect bus.

FUSION SYSTEMS

The Plasma Fusion Center's Fusion Systems Division, headed by Daniel R. Cohn, investigates various aspects of fusion reactor conceptual design, studies applications of other advanced plasma systems such as for plasma waste treatment and X-ray lithography, and develops advanced diagnostics. Current research areas include: CIT design activities (Leslie Bromberg, Daniel R. Cohn); ITER design (Daniel R. Cohn, Leslie Bromberg); commercial reactor design studies (Leslie Bromberg, Daniel R. Cohn, and John E. C. Williams); safety and environmental studies (Mujid Kazimi); X-ray and gamma-ray diagnostic development (Richard D. Petrasso); and millimeter-wave and far-infrared diagnostic development (Paul P. Woskov). Selected technical advances are summarized below.

Compact Ignition Tokamak (CIT) Design: We have continued to perform a number of design variation studies for the CIT, although the scope of these activities has been curtailed in favor of increased emphasis on detailed design issues relevant to the earliest possible construction of CIT at the Princeton site. Requirements for high gain operation (gain = ratio of fusion power to external heating power) were analyzed. High gain operation is a fundamental requirement for fusion power reactors and is a major objective of CIT. Tradeoffs between requirements on the confinement product $n\tau_E$ and requirements on the efficiency of alpha-particle heating were evaluated. Potential benefits of higher aspect ratio plasmas have also been studied, using semi-empirical models for the global confinement time τ_E . In addition, burn dynamics and control have been investigated. We have proposed the use of variable auxiliary heating as a burn control mechanism and have studied its implementation. The CIT group has identified burn control as a major goal and has adopted this burn control technique in its planning. We also investigated the use of a high performance bucked-wedged magnet design scaled to larger size from the Ignitor design of Professor Bruno Coppi. The preliminary analysis indicates that considerably higher current and magnetic field might be possible in CIT. These increases could give substantially increased margin for achieving high gain in a given size device. Use of a super-high-field solenoidal magnet for prototyping the present bucked magnet design has also been studied. Moreover, work is being pursued on various ohmic heating (OH) transformer designs which are evolutionary improvements over the base line design. Finally, key components in a gyrotron heating system, utilizing gyrotrons based on concepts developed in the PFC's Coherent Electromagnetic Wave Generation Division, are being analyzed.

International Thermonuclear Experimental Reactor (ITER) Design: A preliminary design concept for a high-field, high-aspect ratio, lower current ITER has been developed. Potential advantages include reduced machine size, lower fusion power level, decreased tritium consumption, and lower current drive requirements. Substantial cost savings (on the order of 25 percent) appear to be possible with moderate changes in magnet technology requirements. The present ITER conceptual design activity will terminate at the end of this year, and a one year interim phase is expected to occur before initiation of the formal engineering design activity. We anticipate that the present ITER design may be reconfigured during the interim phase, and that our work on higher-field and higher-aspect-ratio concepts may impact the design review process. We have also proposed the use of variable auxiliary heating for burn control in ITER and this approach was adopted for ITER in the conceptual design phase.

Commercial Reactor Studies: The Plasma Fusion Center is participating in the national ARIES commercial reactor design. Activities include overall concept development and magnet design. A high-field, low current concept that uses advanced low-temperature superconductors was proposed by the MIT group. The ARIES team chose this concept for the first reactor design to be developed by the project. This design, ARIES-I, has been completed. The ARIES project is now working on a high field tokamak to be used for advanced fuel operation with D-He³.

Safety and Environmental Studies: Potential safety advantages of fusion energy are being evaluated in a number of activities, including lithium fire modeling and analysis of safety aspects of magnet systems. There is also a study of the radiological waste hazards of the ITER device.

X-Ray and Gamma-Ray Diagnostics: The X-ray and γ -ray experiments group continues to work on the development of novel technologies that allow for the sensitive detection and imaging of high energy radiations (i.e., principally X and γ rays). For example, at The University of Texas at Austin, a multiple imaging X-ray camera was developed, and it is now being used to study the particle and energy transport in the TEXT tokamak. In the γ -ray part of the spectrum, one of the efforts concerns the development of an imaging camera to measure the burn region of near-ignited plasmas, such as would occur, for example, in the Compact Ignition Tokamak (CIT). Renovations have recently been completed in a radiation vault which will be used in the future to test and develop a new class of experiments designed for both laboratory and space environments. This latter program is being coordinated with the MIT Center for Space Research. A new program, under the sponsorship of the Lawrence Livermore National Laboratory, has also recently begun to train students in X-ray and γ -ray technologies.

Millimeter-Wave/Far-Infrared Diagnostics: An effort is underway to develop a diagnostic to measure the velocity and spatial distributions of energetic ions using Thomson scattering of millimeter-wave gyrotron radiation. This measurement will provide information on fundamental aspects of plasma self-heating by alpha particles. A major collaboration has been proposed by the Joint European Tokamak (JET) group and has been encouraged by DOE. The Plasma Fusion Center would play the lead U.S. role in this collaboration. In addition, an ultra-wide-bandwidth heterodyne receiver concept has been developed for measuring electron cyclotron emission. These measurements would be used for high resolution determinations of fluctuations in second stability plasmas. A proposal has been made to use this diagnostic on the PBX-M tokamak at Princeton, where it would be used to detect and characterize MHD modes which may occur in our pursuit of the so-called second regime of stability.

Pilot Plant Design Study: Preliminary design approaches have been developed for a pilot plant that would provide an early demonstration of the generation of electricity from fusion. The pilot plant would use advanced technology to minimize size, fusion power level, and cost. The objective will be to design a plant that would produce electricity by 2005-2010 with the most advanced materials available. These materials may well be less advanced than those used in a Demonstration Reactor, the last step before commercial development. A range of designs with goals between those of a pilot plant and those of a demonstration plant will be studied. A joint proposal to DOE for a design study has been made with Oak Ridge National Laboratory and Fusion Power Associates. MIT will give particular emphasis to high-field, high-aspect ratio concepts. New magnet design approaches with advanced materials will be investigated.

Plasma Systems for Waste Treatment: Initial scoping studies have been made for use of plasmas to treat waste. Plasmas would be used both to gasify waste and to destroy toxic materials in the gas. The use of plasmas could provide important advantages relative to conventional high temperature incineration. These advantages include substantially lower gas throughput and much higher toxic material destruction and removal efficiencies. Plasma sources may be particularly well suited for local waste processing. Particular emphasis is given to plasma pyrolysis. New concepts have been developed for electrodeless, high density thermal plasmas. A preliminary design will be developed for a special inductively heated arc plasma. Meetings have been held with companies that do incineration in order to develop approaches that meet user needs. Funding for a joint university-industry program is being pursued.

COHERENT ELECTROMAGNETIC WAVE GENERATION

The primary objective of the Plasma Fusion Center's Coherent Electromagnetic Wave Generation Division, headed by Richard Temkin and George Bekefi, is to develop a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in a 1 micron to 1 cm wavelength range. Particular emphasis is placed on the development of gyrotrons (Kenneth Kreisler), free electron lasers, and novel radiation sources. A second area of research relates to theoretical studies of the basic equilibrium and stability properties of non-neutral plasmas and intense charged particle beams, with applications to high-current accelerators, coherent radiation generation, and nonneutral electron flow in high-voltage diodes (Ronald Davidson, Jonathan Wurtele). A third area of research is high power microwave sources including the relativistic magnetron (Shien-Chi Chen) the cyclotron autoresonance maser (CARM) (Bruce Danly) and the free electron laser. A fourth area of research relates to basic theoretical and experimental investigations of high gradient acceleration.

In the area of gyrotron research, gyrotrons with output powers in the 0.4-1.2 MW range at frequencies between 140 and 320 GHz and pulse lengths of three microseconds have been studied experimentally. These represent new records in output power and frequency for gyrotron devices. Such gyrotrons can be developed by industry into long-

pulse or CW tubes for application to plasma heating. Work continues on extending the operating frequency to 280 GHz with a power level of one megawatt for eventual application to plasma heating on the Compact Ignition Tokamak (CIT). This research is carried out in collaboration with Varian Associates, Palo Alto, CA, which is constructing a novel electron gun for this program. A 12 T superconducting solenoid with a room temperature bore is also being fabricated for these experiments. The extension of gyrotron operation to higher frequency will require novel ideas for solving the problem of mode competition in highly overmoded gyrotron cavities. The role of electron beam quality in the saturation of the gyrotron interaction will also be investigated.

In addition to research on high power gyrotron oscillators, investigations are underway on two related, novel gyrotron devices. One device is a harmonic gyrotron. This device allows even higher frequency radiation to be achieved at kilowatt power levels. Frequencies of up to 500 GHz in microsecond operation have been obtained. The second device is the gyrotron backward wave oscillator. This is a promising source of tunable, kilowatt power level radiation at frequencies near 140 GHz. Research is also underway on novel antennas for launching high frequency gyrotron radiation into plasmas or transmission lines.

A long-pulse relativistic magnetron microwave (3 GHz) source using a superconducting magnet has been designed and constructed and is now under test. The power supply for this experiment (700 kV, 750 A, 1 microsecond) has been built and tested. The goal of this research is to demonstrate long pulse operation of magnetrons at very high powers, up to 100 MW of output power. The magnetron will be phase locked using a 1 MW, tunable pulsed oscillator. The required injected power to achieve phase locking and the degree of phase locking will be investigated.

The cyclotron autoresonance maser (CARM) is a novel, high power microwave source which appears capable of operation at high frequency, into the millimeter wave range. A long pulse, CARM oscillator/amplifier has been constructed using the same power supply as described above in the relativistic magnetron research program. Preliminary results have recently been obtained using an electron gun fabricated by the Stanford Linear Accelerator and a long bore, superconducting magnet. A CARM oscillator was operated at both the fundamental frequency, between 30 and 35 GHz, and at the second harmonic frequency, near 70 GHz. Using a 250 kV, 12 A beam, power levels exceeding 20 kW in a one microsecond pulse were obtained. A free electron laser experiment is presently under construction using the same power supply. A 700 kV, 80 A electron gun has been built by Thomson Tubes Electronique in Paris and shipped to MIT for use in this experiment.

A new area of research is the investigation of electron accelerators with high gradients. Such accelerators are needed to upgrade existing facilities or to construct new facilities such as the next generation linear collider. Experiments at 17.1 GHz are planned using a CARM amplifier powered by an induction linear accelerator (ILAC). The ILAC, which operates with 1 MeV, 500 A, 50 μ s pulses at 1 kHz repetition rate, is located at the Plasma Fusion Center on loan from Science Research Laboratory of Somerville, MA. The ILAC is also used in a relativistic klystron experiment operating at a frequency near 10 GHz.

APPOINTMENTS AND PROMOTIONS

During the past year, there have been several important appointments and promotions in Plasma Fusion Center program areas.

Appointments include: Mikhail Fridberg (National Broadcast and Acoustic Center), appointed RF Engineer in the Toroidal Confinement Division; Paul Lindsay (Massachusetts Institute of Technology), appointed Principal Research Scientist in the Applied Physics Research Division; John Machuzak (Massachusetts Institute of Technology), appointed SRS-Postdoctoral in the Fusion Systems Division; and Kevin Wenzel (Massachusetts Institute of Technology), appointed Postdoctoral Fellow in the Fusion Systems Division.

During the past year, promotions in the Plasma Fusion Center have included: Paul Bonoli, promoted to Principal Research Scientist in the Toroidal Confinement Division; William Beck, promoted to Materials Engineer in the Toroidal Confinement Division; Robert Granetz, promoted to Principal Research Scientist in the Toroidal Confinement Division; Kenneth Kreischer, promoted to Principal Research Scientist in the Coherent Electromagnetic Wave Generation Division; Lissa Natkin, promoted to Assistant Fiscal Officer in the Fiscal Office; Richard Petrasso, promoted to Principal Research Scientist in the Fusion Systems Division; and Dieter Sigmar, promoted to Senior Research Scientist and Leader, Theory and Computations Group in the Applied Physics Research Division.

During the past year, the Plasma Fusion Center has also hosted many Visiting Scientists, Engineers, and Scholars in the various research programs. They are: Mr. Dawood Aized (Massachusetts Institute of Technology), thermal stability of cable-in-conduit conductor with double conduit; Dr. Joaquim Barroso de Castro (Institute of Space Research, Brazil), theoretical gyrotron design; Dr. Margalit Ben-Ari (Armament Development Authority, Israel),

plasma theory and computations; Dr. Daniel Birx (Science Research Laboratory), induction linear accelerator work; Dr. Franklin Chang-Diaz (NASA), plasma propulsion; Dr. Dennis Clarke (Science Research Laboratory), induction linear accelerator work; Prof. John Davies (Clark University), theory of free electron lasers; Dr. Giulio Flor (Istituto Gas Ionizzati, Italy), systems programming for data acquisitions; Dr. Henry Freund (Science Applications International Corporation), coherent radiation generation by free electron lasers; Dr. Daniel Goodman (Science Research Laboratory), induction linear accelerator work; Dr. Alexander Gurevich (Lebedev Institute, USSR), radiowave-plasma interactions in the ionosphere; Dr. Scott Haney (Lawrence Livermore National Laboratory), burn control for ITER; Dr. Frederic Hartemann (Thompson CSF, France), cyclotron autoresonance maser and free electron laser research; 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. Guishi Luan (Institute of Plasma Physics, PRC), advanced tokamak magnet systems and plasma-wall interactions; Dr. Gabriel Manduchi (Istituto Gas Ionizzati, Italy), data acquisition and controls; Dr. Keith Miller (Sheffield University, England), mechanical testing program for CIT and multi-axial fatigue; Mr. Neil Morley (University of California at Los Angeles), high powered, high frequency gyrotrons; Dr. Paul Moroz (Lebedev Institute, USSR), RF heating theory; Dr. Jacek Myczkowski (Massachusetts Institute of Technology), theory of lattice gasses to simulate fluid dynamics on special purpose computers; Dr. Shigehiro Nishijima (Osaka University, Japan), cryotribological characterization of fiber reinforced materials; Ms. Sherrie Preische (Princeton Plasma Physics Laboratory), fluctuation diagnostics; Dr. Yi-Kang Pu (SPIRE Corporation), electron cyclotron resonant ion source physics; Mr. Robert Randall (Supercon, Inc.), mechanical, material and metallurgical problems in superconductivity; Mr. Sean Reilly (Graphic Products Corp.), computer support for the plasma ion source project; Mr. Ralph Scheid (Technical University, West Germany), superconducting magnet development work; Dr. Frederick Seguin (American Science and Engineering), x-ray tomography on Constance; Dr. Donald Smith (Massachusetts Institute of Technology), RF systems; Mr. Yasuyuki Tahara (MRI at Mitsubishi Electric, Ako Works, Japan), superconducting magnet technologies; Dr. Osami Tsukamoto (Yokohama National University, Japan), superconducting magnet technology; Dr. Gerard Vichniac (Bolt, Berenack and Newman), theoretical plasma physics; Dr. Reich Watterson (Science Research Laboratories), novel laser scattering diagnostics; Dr. Kongyi Xu (Chengdu Institute of Radio Engineering, PRC), high frequency gyrotrons; Ms. Ge Zhang (Clark University), theory of free electron lasers; and Dr. Zong-Ping Zhao (Tokyo Denki University, Japan), theoretical aspects on the design of high TC conductor magnets.

GRADUATE DEGREES

During the past year, the following students graduated with theses in plasma fusion and related areas: Emmanouil Chaniotakis, Ph.D. in Nuclear Engineering; Chikuang Chen, Ph.D. in Mechanical Engineering; Kyu Sun Chung, Ph.D. in Nuclear Engineering; David Corbin, M.S. in Mechanical Engineering; Thomas Farish, Ph.D. in Nuclear Engineering; Jamie Geschwindt, M.S. in Mechanical Engineering; Olivier Herbelot, M.S. in Nuclear Engineering; Robert Kirkwood, Ph.D. in Nuclear Engineering; Bhavya Lal, B.S.S.M. in Nuclear Engineering; John Machuzak, Ph.D. in Nuclear Engineering; Robert Miller, M.S. in Mechanical Engineering; Ige Oluwasegun, Ph.D. in Mechanical Engineering; Marie Oshima, M.S. in Nuclear Engineering; Craig Petty, Ph.D. in Nuclear Engineering; Justin Schwartz, Ph.D. in Nuclear Engineering; William Stewart, M.S. in Nuclear Engineering; Kevin Wenzel, Ph.D. in Nuclear Engineering; and Frank Wong, Ph.D. in Nuclear 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 75 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 a few 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.

Within RLE, there is a substantial emphasis on the epitaxial growth of materials at atomic layer resolutions using both molecular beam epitaxy and chemical beam epitaxy. Professor Jesus del Alamo has investigated the effective strain in indium aluminum arsenide/indium gallium arsenide (InAlAs/InGaAs) heterostructure field-effect transistors on indium phosphide. The goal of this work is to use the strain introduced by lattice mismatch to improve the performance of these devices for microwave and light-wave communication systems. Several different devices have been fabricated, with properties suitable for high-power applications such as high-gain, small signal requirements. Professor Clifton Fonstad has introduced a remarkable new means for providing electrical contact to the quantum well in a resonant tunneling diode. This new capability permits the realization of an entirely new class of high-performance devices that may be called quantum well-based tunnel barrier (QT) devices. He has also produced resonant tunneling diodes for the highest operating current densities ever recorded. This will be useful for high-power microwave oscillators. During the winter, Professor Leslie Kolodziejewski took delivery on a major new chemical beam epitaxy facility, designed and constructed to her specifications. The major objective now is to bring this system up to its complete potential, and exploit it to grow thin films of zinc selenide. Professor Carl Thompson has continued investigations of microstructural evolution in epitaxial, polycrystalline, and amorphous films. He has conducted several studies on the reliability of interconnect structures as a function of the distribution of grain size. When the distribution remains narrow, the average grain size does not affect reliability of these interconnects. Although, large grains contribute to structures that include fewer triple grain boundary junctions per unit volume, thus decreasing the probability of electromigration incidents at these sites. Grain growth and thin films have also been modeled successfully by computer simulation, so it will now be possible to simulate electromigration phenomena in a wide variety of thin-film structures. Professor Henry Smith has exploited submicron and nanometer structures in many applications. A self-aligned silicon MOSFET measuring two-tenths micron channel length was constructed. This permitted integrated circuit densities more than an order of magnitude higher than the current state of the art. In addition, holographic techniques were applied to the fabrication of large area gratings of 50-nanometer lines and spaces. These are expected to lead to new high-mobility semiconductors with numerous applications in electronic and computation systems. In addition, these exceedingly small structures form the experimental basis for the investigation of quantum phenomena in the solid state, where new, heretofore unseen characteristics may lead to radically novel devices. Principal Research Scientist Dr. John Melngailis has used two focused ion beam systems to study direct maskless, resistless implantation in lithography, and to repair integrated circuits and masks. Graded doping techniques have permitted the construction of a widely tunable Gunn diode as well as new charged-couple devices with dramatically improved speed. Ion-induced deposition has been used to deposit platinum from an organometallic precursor gas, and very narrow gold lines (which can be used in x-ray masks) have been reliably

fabricated at widths of 50 nanometers. Lastly, these techniques are being applied in a new monolithic microwave integrated-circuit program for the production of high-frequency gallium arsenide circuits. Professor Sylvia Ceyer has continued her studies of the etching of silicon surfaces through the introduction of fluorine molecules. A new phenomenon called "fluorine atom abstraction," where the silicon surface strips off one of the fluorine atoms from the fluorine molecule, has been discovered. In a plasma etching environment, this behavior may provide a mechanism for radical generation, in addition to those behaviors generated by the plasma itself. Professor Keith Nelson has focused on the interaction of light with matter, using ultrafast optics and spectroscopic techniques. Specifically, he has used femtosecond optical sequences for control over molecular motion in the lattice, as well as the observation of shear acoustic waves in liquids. These results are expected to be useful for exceedingly high-frequency optical communications and information processing, as well as the optical fabrication of materials.

In the optics research area, Professor Hermann Haus has continued to work with Professor Erich Ippen and Professor James Fujimoto on the novel additive pulse modelocking technique that has recently been developed. This technique provides a new way to produce very short optical pulses from solid-state lasers. The theory of this process has been worked out, and the technique has been used to generate pulses with a variety of solid-state lasers for which no previous technique was applicable. In addition, Professor Haus has developed a theory for the proper quantum description of optical pulses, which is needed to characterize the behavior of these pulses when they are "squeezed." Successful experiments have been introduced to produce such nonclassical states, which can be used for a variety of communication needs. Professor Ippen has used femtosecond pulses to probe characteristics of superconducting materials, enabling the measurement of electron-phonon coupling which was achieved directly for the first time. In addition to his contributions to the studies of additive pulse modelocking, Professor Fujimoto has continued investigations of transient processes in optoelectronic materials, concentrating on metals. He has been able to reveal the behavior of image potential states in metals, which are of interest in fundamental physics because they provide a model to study electron tunneling dynamics. Professor Fujimoto has also applied ultrashort-pulse laser technology to laser medicine and surgery. Here, the goal is to investigate the interaction of short laser pulses and biological tissues in order to develop new surgical approaches. Specifically, his objective is to develop an ultrashort-pulse laser scalpel that can perform surgical incision of intraocular structures using high-intensity nonlinear laser tissue interaction. Professor Peter Hagelstein is engaged in the design and construction of a "desk-top" x-ray laser. This project has many activities, including the design of a vacuum chamber, a power amplifier, and novel "whisper gallery" laser cavities; and the development of new algorithms for x-ray laser kinetics calculations. A new x-ray detector has been developed that can overcome signal-to-noise problems at easily realizable x-ray fluxes. Professor Hagelstein has also developed a new scenario for a coherent heat-producing reaction which appears to be qualitatively consistent with numerous positive "cold fusion" experiments. In addition, he has specified several key experiments to test the coherent fusion scenario.

In condensed matter physics, several theoretical and experimental studies are coordinated to provide insight into many novel states of matter. Professor Robert Birgeneau has studied metal and semiconductor surfaces at high temperatures. Recently, he has used high-resolution synchrotron x-ray scattering techniques to study the germanium (111) surface. At high temperatures (approximately 1050°K), he has been able to show that there is actually no phase transition, as previously thought; but, in fact, a continuous evolution of surface structure. This new model for the behavior of semiconductor surfaces at high temperatures is typical of integrated circuit manufacturing practices, and has important implications for layer growth (which can now be characterized at the atomic level). Professor John Joannopoulos has developed a new model of semiconductor heteroepitaxy based on theoretical simulation starting from first principles. This model can take into account the nature of the growth mode under varying external conditions, the importance of various surface morphologies, and the identification of chemical and rehybridization reactions that control growth. Taking advantage of semiconductor processing technology, Professor Marc Kastner has studied semiconductors so small that they contain less than 100 electrons. Remarkably, it has been discovered that a transistor at this dimension may change its characteristics by as much as two orders of magnitude whenever a single electron is added to it. This behavior has led to new physical phenomena which are not yet understood, but may lead to a useful device if the phenomena can be reproduced at normal ambient temperatures. This work can be seen as an addition to the rapidly accumulating knowledge of electron behavior in very small structures. These very small structures, in the form of a narrow quantum wire, have been theoretically modeled in a strong magnetic field by Professor Patrick Lee. By calculating the conductance of these wires, finite-size corrections to the quantum Hall effect (as well as conductance fluctuations between Hall plateaus) have been achieved. Professor Nihat Berker has studied the effect of impurities on phase transition signals, and also the finite-temperature phase diagrams and step profiles associated with semiconductor surfaces. Working with Professor Joannopoulos, he has developed a theory for phase transitions between differently stepped silicon (100) surface phases in a way that combines precise electronic calculations with finite-temperature statistical mechanics. Professor John Graybeal has examined novel hybrid semiconductor superconducting devices. These devices have a characteristic energy needed to modulate the device, which is set by the quantum confinement energies. Providing a significant qualitative advance over current devices. Several of these experimental devices have been built, and their electrical characteristics are being determined. In the VLSI circuit design area, Professor John Wyatt and his collaborators continue to design an analog integrated-circuit image acquisition system that can be used to detect shapes and velocity vectors. A new technology that incorporates both charged-couple devices and basic CMOS

capability has been constructed, and fundamental results have been achieved concerning the stability of analog arrays present in the system. In a major advance, Professor Srinivas Devadas has combined state-of-the-art synthesis of digital systems with new capabilities for testability. Both combinational and sequential circuits can now be synthesized in optimal ways that have no redundancy, and hence are highly testable. This technique has been tested in the design and construction of a large speech recognition chip. Theoretical work and formal verification that allows for equivalence checking between behavioral specifications and logic implementations have also been completed. Professor Jacob White has focused on the use of numerical techniques for circuit and device simulation. A new, highly accurate, and efficient three-dimensional capacitance extraction program has been completed. Furthermore, new techniques for transient device simulation have used a more refined theory for the convergence of the waveform relaxation technique used in this algorithm. They have also yielded an increase of nearly an order of magnitude in speed compared to direct techniques. Professor Jonathan Allen has developed techniques for performance-directed synthesis of VLSI circuits. Emphasis has been placed on the means for synthesizing quasi-array-type structures from a high-level behavioral specification, in a way that restricts interconnect to a variable local neighborhood surrounding each element of the array. Techniques for maintaining consistency between various design representations have also been introduced, and are leading to a general structure for the representation of all design levels, together with automatic alignment procedures between them.

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. Research in the speech communication group has examined several questions that relate to processes of speech production at the levels of planning, articulatory movements and coordination, and sound generation. Based on a large corpus of speech errors in both spontaneous and elicited speech, a model of the phonological planning process has been developed. Research continues on the acoustic and perceptual correlates of phonetic distinctions across languages, with emphasis on consonants for which the acoustic mechanisms involve parallel resonators or turbulence noise. These studies provide the bases for refinements of models used in both speech synthesis and speech recognition. Senior Research Scientist Dr. Joseph Perkell has studied basic properties of speech articulation. Interestingly, the nature of some speech articulation has been shown to be influenced by the competing constraints provided by preferred gestural kinematics, as contrasted to the acoustic requirements of the sounds in the sequence being produced. These and other studies are leading to a new understanding of motor control in speech production. Studies of the speech of cochlear implant patients have also been completed, and show contrasting respiratory acoustic and glottal patterns in subjects before and after use of the cochlear prosthesis.

Research on sensory communication is conducted by Professor Louis Braidă, 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. Work continues on the study of normal and impaired hearing, and the development and evaluation of aids for the deaf. In addition, a new general-purpose multimodality interface has been developed for the study of teleoperator systems, which involves the interaction of humans with remote manipulation equipment. These studies have characterized the human hand's ability to sense and manipulate the physical environment, as well as human adaptation to altered sensorimotor loops associated with the use of nonanthropomorphic slave robots. Studies of the human hand are focused on the resolution of length and force, and how dexterity is degraded by various constraints, deformations, and sensory losses in the hand.

In cooperation with the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary, long-range studies on the hearing mechanism are pursued. The main emphasis is to understand auditory physiology by describing signals and mechanisms throughout the pathway from the external auditory meatus to the auditory cortex. Professor William Peake and Research Scientist Dr. John Rosowski have extended their model of sound/power transfer through the external and middle ear to instances of sound-induced hearing loss by quantifying the action of the middle and external ear in limiting the combinations of sound frequency and level which damage the inner ear. These studies have shown that many of the frequency-specific effects of intense broadband sound can be explained by the filtering of acoustic power by the external and middle ear. Professor Thomas Weiss has developed a new *in vitro* preparation of the cochlea of a reptile. The cochlea is dissected and placed in the chamber on the stage of a compound microscope. A culture medium has been found that adequately preserves the viability of the cochlea for further study. This preparation will be used to study the motion of the cochlea structures in response to hydrodynamic stimulation. Research Scientist Dr. Donald Eddington and his collaborators have studied the electrical stimulation of the human auditory system using cochlear implants. Twenty human subjects have received implants, and their progress is being studied. In addition, the modeling of current spread in the inner ear during intracochlear stimulation is also leading to a new understanding of how these cochlear prostheses aid the perception of speech. There has been continuing development of a software model that predicts potential distributions along the scala tympani for several stimulation sites. As the modeling work expands to include nerve fiber activity,

it will provide a basis for understanding the perceptual experiments based on electrical stimulation. In this way, it should be possible to design better sound processing schemes to control the electrodes of the prosthesis. This will lead to improved speech recognition for deaf subjects using these electrodes.

FOCUS AREAS

Atomic, Molecular, and Optical Physics

Professor Shaoul Ezekiel has developed a new optical rotation sensor for a gyroscope, based on the use of a stimulated Brillouin ring laser in a fiber. This is the first demonstration of an all-solid-state bidirectional ring laser. In addition, he has demonstrated that the absorption of an optical field can be controlled by the phase of a microwave field. This may have applications in real-time holographic image conversion and in beam steering. Professor David Pritchard has used new experimental techniques to improve the precise measurement of atomic masses, raising the state of the art for precision in mass measurement to 4×10^{-10} . This is a first step toward the ultimate goal of 10^{-11} or better. Such capability would permit a variety of experiments that address issues in both fundamental and applied physics, such as: measuring the rest mass of the neutrino; determining Avogadro's number accurately enough to replace the artifact mass standard with a more atomically based standard; and ultimately, determining the energy of chemical bonds from the "lost" mass of a molecule, relative to its constituents.

Plasma Physics

The generation of femtosecond pulses in lasers has been achieved over the last several years, but Professor George Bekefi is now designing techniques to generate similar radiation bursts (or spikes) in the nonlinear regime of free-electron lasers. These studies may lead to a better understanding of the free-electron laser oscillator start-up phase, and to methods of generating trains of very short and tunable micropulses, both in microwave and optical free-electron lasers. Professor Abraham Bers has conducted several fundamental studies aimed at understanding transport in rf heating and current drive of plasmas, which may also have an impact on understanding global transport in plasmas due to turbulence. These studies characterize the nonlinear dynamics of intrinsic stochasticity and chaos in plasmas, and relate these to plasma heating with electromagnetic power. Such chaotic dynamics in magnetically confined plasmas, which are induced by the action of electromagnetic fields, has shown the existence of nondiffusive transport of plasma particles. Professor Bruno Coppi has studied the physics of plasmas, both in magnetically confined laboratory experiments and in space. Special emphasis is placed on the achievement of controlled thermonuclear fusion, including the understanding of transport processes and associated microturbulence in experiments, and instabilities in astrophysical systems such as ionospheres and magnetospheres. New theoretical results have led to an improved understanding of the conditions needed for thermonuclear burning. These concepts are leading to an experiment that can burn cleaner fuels in new reactors. Several studies using the Versator II research tokamak have been conducted by Professor Miklos Porkolab and his students. New techniques for fast wave current drive have been introduced, electron cyclotron heating and plasma start-up have been provided by using a gyrotron source, and new studies of the "second stability" regime have been made for the first time on a tokamak.

Radio Astronomy

Professor Bernard Burke has used the Very Large Baseline Interferometer (VLBI) to study gravitational lens systems. These observations do not match any current theoretical predictions, so a variety of new experiments are being formulated to capture a comprehensive array of new data. Professor Jacqueline Hewitt has also collaborated with Professor Burke in the identification of several gravitational lens systems. She is also using VLBI techniques to study nearby stars, and to investigate the stability of their radio emissions. Professor David Staelin has compared radio emissions from Neptune, Jupiter, Saturn, and Uranus in a way that suggests the dominant radio emission mechanism is similar on all the Jovian planets, and that it must be robust in view of the very different physical conditions encountered.

Image Processing

Professor Donald Troxel has implemented software to control the fabrication of integrated-circuit wafers with processing specified and described by a process flow representation (PFR). It is now possible to simulate and fabricate integrated circuits from process descriptions in PFR, so that designs may first be accurately simulated and then fabricated with good correspondence between the physical circuits and the simulated versions. Professor William Schreiber, who for many years led the Advanced Television Research Program (ATRP), has taken a sabbatical and retired. He has transferred leadership of ATRP to Professor Jae Lim. Work in ATRP is described in the following section.

Digital Signal Processing

Professor Alan Oppenheim has developed a wide variety of new algorithms for application in areas such as speech, image processing, video processing, and geophysical signal processing. These innovative algorithms are also characterized in terms of novel computer architectures, on which they can be efficiently executed. In addition, both numerical and symbolic techniques are being combined to form a set of new techniques known as knowledge-based signal processing. In this way, purely numerical techniques are being extended to provide a much richer class of algorithms. Professor Jae Lim, who is now leading the Advanced Television Research Program (ATRP) following the retirement of Professor William Schreiber, has used new techniques made possible by VLSI technology and signal processing theories which incorporate frame-store memory and sophisticated signal processing capability in television receivers that can be manufactured at a reasonable cost. A channel-compatible advanced television system has been designed, and it is scheduled to be tested in 1991 for possible adoption as the U. S. high-definition television standard for terrestrial broadcasting. A receiver-compatible advanced television system, which is a significant improvement over the existing system, has also been designed.

Electromagnetics

Professor Jin Au Kong and his research group have worked on a wide range of electromagnetic theory problems and corresponding applications. They have studied applications to microwave and millimeter-wave integrated circuits, microelectronic circuit packaging, microstrip antennas, geophysical subsurface probing, active and passive remote sensing of earth terrain, synthetic aperture radar imaging, radar cross-section prediction, interference phenomena for automatic landing systems, and time-domain electromagnetic wave propagation and coupling problems. As an example, the study of electromagnetic wave propagation in integrated circuits has required new methods of accurate analysis. Time-domain solutions to these problems have been achieved by use of finite-difference methods, the method of characteristics, and integral transform methods based on scattering parameters. Frequency-domain problems are investigated by using a dyadic Green's function and integral equation formulation together with a method of moments. In this way, a broad theoretical base serves the needs of many applications in a rich variety of contexts.

Communications

Professor Jeffrey Shapiro and Research Scientist Dr. Ngai Chuen Wong have focused on the generation and application of nonclassical light beams, as well as laser radar system theory. Recently, they have continued their development of the quantum theory of phase. Relying extensively on analogies with optical heterodyne detection and with linear system theory, they have identified new classes of nonclassical light states that are relevant to phase measurement, and place the number-phase uncertainty principle on a firm theoretical foundation. Additionally, they have provided the first quantitative predictions of the performance advantages that accrue from multidimensional active-passive target detection in laser radar systems. These predictions have been experimentally verified by tests at MIT Lincoln Laboratory. Senior Research Scientist Dr. Robert Rediker has continued to optimize the operation of a fiber-coupled external cavity laser. Five discrete semiconductor lasers have been made to operate as a coherent ensemble in this apparatus. These new coupled lasers provide a high-power capability that will open up many new applications for semiconductor lasers, so that they will become the laser of choice, except for very special applications.

In addition to the focus areas described above, several other research directions have been pursued within RLE. Professor Campbell Searle and Professor Jerome Lettvin have continued their work on the model of a control process for sodium and potassium channels in nerve fibers. This work is aimed at the fundamental understanding of the generation of nerve impulses. They have also extended their modeling of hair cell transduction in the auditory cochlea, in an effort to match the published physiological data characterizing these processes. Professor Sow-Hsin Chen has used thermoneutron scattering techniques to study the structures of macromolecules and super molecular aggregates in solution. The behavior of protein molecules in solution has been comprehensively modeled in a way that characterizes the polymer-like phase separation in electrophoretic mobility of the protein complex. Recently, these predictions have also been experimentally verified.

JONATHAN ALLEN

Sea Grant College Program

Congress established the Sea Grant College Program in 1966 to address the need for responsible development and management of marine resources. Existing programs of marine research and education at the nation's universities were recognized as important sources of information in this emerging field, and so a national program was created to provide them with financial support. The MIT Department of Ocean Engineering received one of the first grants in 1969 to develop a series of innovative texts. One year later, a larger "Sea Grant" was made to the Institute for a full research and education program. By 1976, MIT's Sea Grant contribution was so significant that the Institute was designated a Sea Grant College, the first private university to receive this recognition.

There are 29 Sea Grant Programs throughout the coastal and Great Lakes states. Funds are distributed among programs in a competing grant process by the National Oceanic and Atmospheric Administration through the 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 both its research program and its mandate for advisory services and education.

Last year the Office of Sea Grant awarded MIT \$1.64 million; an increase of \$100,000 from the previous year and the first increase in more than six years. MIT, industry partners, the Commonwealth, the Massachusetts Water Resources Authority, the U.S. Olympic Committee, and the U.S. Rowing Association provided nearly \$1.5 million in matching funds. In addition, MIT Sea Grant also received more than \$600,000 in related research support from other federal agencies. In all, these funds supported 18 faculty and 24 students from eight departments including Civil, Chemical, Ocean, and Mechanical Engineering; Electrical Engineering and Computer Science; Aeronautics and Astronautics; Physics; and Earth, Atmospheric and Planetary Sciences.

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 on 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 and smooth 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. In particular, this research works to describe the effects of various flow irregularities, in front of or behind a propeller unit. The automation theme area has attracted substantial collateral support from the National Science Foundation, Naval Sea Systems Command, and the Office of Naval Research.

Research in *marine biotechnology* is directed toward developing technologies for producing high-value products from marine resources and advancing techniques to promote improved marine resource productivity. Researchers developed methods to evaluate the chemical composition of various fish oils, with an eye toward evaluating the stability of fish oils in accelerated and long-term storage and incorporating fish oils into food products. Other researchers continued to investigate a novel biotechnology that seeks to improve fish reproduction in aquaculture systems through controlled release of implanted fish hormones. Two important milestones were reached in the utilization of chitin and chitosan. An extensive 500-page bibliography titled,

Chitin Sourcebook: A Guide to the Resource Literature, was published by John Wiley and Sons Inc. Despite its high price (\$150), the book has proven very popular. A second milestone was reached when the Chitin Co., founded by E. Ray Pariser (MIT Sea Grant associate director for education emeritus), was purchased by DuCon, a Du Pont/ConAgra company. This acquisition was strong evidence for chitin's many commercial applications.

Interdisciplinary Sea Grant investigations of *ocean and coastal processes* seek to describe and model the behavior 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. And, one project completed work on a chronology of the events surrounding the degradation and cleanup of Boston Harbor since its settlement in 1630. Research support in this theme area has also come from the Massachusetts Water Resources Authority. Additional research on Massachusetts Bay is carried out under Sea Grant's Marine Center project.

And, in their continued commitment to the harbor, MIT Sea Grant researchers maintain their leading role in establishing and working on statewide coordinating efforts for Boston Harbor and Massachusetts Bay. For example, through the efforts of Sea Grant's Marine Industry Collegium, researchers gather annually with representatives from other agencies to develop a coordinated agenda for water and sediment quality research in Massachusetts Bay.

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. Other participants in this ambitious effort include MIT's Department of Ocean Engineering's Design Laboratory, Department of Mechanical Engineering's Fluid Mechanics Laboratory, and Plasma Fusion Center. Additional financial support has been received from Naval Sea Systems Command and the Office of Naval Research. In related research, Sea Grant is investigating new structures for lightweight hulls for very deep submersibles (6000m).

Sea Grant receives support from several U.S. Navy labs to study the operational behavior of marine ropes and cables. This research, prompted by safety concerns and hazard prevention, has yielded valuable data on the pathology of synthetic rope deterioration and the effects of abrasion and tensile loading on rope strength. The projects seek to develop models to predict the breaking point and working lives of ropes in a variety of marine applications, including towing. In a separate but related program, Sea Grant receives Navy funds to analyze loads on tow ropes and cables in sea conditions where both the tug and tow are subject to large ranges of motion. Together, these projects will improve the safety and efficiency of both commercial and naval marine operations.

Under the theme area of *technology development for ocean uses* is the Marine Center, which provides marine industries and other government agencies a way to furnish funds to facilitate the transfer of technologies from MIT laboratories to their own. In addition, Sea Grant is advised of industry interests and needs in ocean research through Marine Center participants, as well as Sea Grant's Marine Industry Collegium members. The Marine Center, which has traditionally funded a handful of smaller projects, has shifted its focus to concentrate on fewer, larger projects. The first project of this kind began to address coastal water quality, focusing on management of coastal algal blooms and contaminated sediments. Investigators researched areas of trace element regulation of nuisance algal blooms, such as red tides; sediment-water exchange of toxics; and modeling of water movement. Researchers hope to employ a remotely operated vehicle or an autonomous underwater vehicle to conduct some of the sediment sampling.

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. An important milestone has been the integration of supervisory control and layered control in a single architecture, providing useful control techniques for remotely operated vehicles as well as autonomous ones. The project is sponsored by Sea Grant, Naval Sea Systems Command, Northrop Corp., International Submarine Engineering Ltd., and other prospective partners.

Other work on underwater systems is carried out under Sea Grant's general 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 a 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.

To encourage the development of new research ideas, Sea Grant sponsors several seed projects annually. Last year a number of diverse projects included the design and construction of a human-powered hydrofoil and a human-powered submarine. Additional funding was also provided for a prison aquaculture project in which inmates raise fish and vegetables in hydroponic tanks. Matching support was provided for research aimed at developing faster rowing shells for the U.S. Olympic teams, and for work on sliding control techniques for robot arms in underwater vehicles.

ADVISORY SERVICES

MIT Sea Grant continued to make strides in its ongoing four Advisory Services projects—the Marine Industry Collegium, the Center for Fisheries Engineering, the Massachusetts Marine Liaison Service, and Communications/Information Service—and also expanded to add a fifth project to provide support for faculty and graduate students to apply their research to problems in coastal communities.

The Sea Grant Marine Industry Collegium, the first industry collegium on campus, is the program's primary vehicle for technology transfer. The Collegium membership fee entitles companies to attend several technical workshops each year to meet with faculty and students and to review research in progress. In addition, the Collegium serves as a liaison between industry representatives and researchers and provides its members with access to a nationwide network of Sea Grant publications. Last year workshop topics included design of motors and propulsors for small underwater vehicles; structural acoustics; water and sediment quality in Massachusetts and Cape Cod Bays; and advances in imaging technology, which was held in conjunction with the Industrial Liaison Program.

MIT Sea Grant's Center for Fisheries Engineering continues to be an important resource to the region, and the nation, on the technical aspects of commercial fishing. With the recent development of the Center's Towed Underwater Gear Observation System (TUGOS), the Center now has the unique capability to observe trawl nets and dredges in situ to learn the behavior patterns of different size and species of fish. This, combined with the model testing facilities the Center uses regularly at the David Taylor Research Center (DTRC) in Bethesda, Md., allows the development of more selective and resource-sparing nets. TUGOS is also proving to be of value in bottom surveys of living resources. The hydrodynamic test facilities at DTRC have further served the industry through tests for trawl manufacturers and courses for trawl fishermen on how to achieve peak performance from their nets. Recent tests have included resistance and seakeeping studies on open-ocean aquaculture pens. On a smaller scale, projects have also been undertaken in the MIT tow tank on ways to control roll motions of fishing vessels.

For the seventh year, the Massachusetts Marine Liaison Service (MMLS) coordinated Coastweeks, a statewide celebration involving more than 75 organizations that sponsored 150 activities and attracted thousands of participants. Events were designed to increase the public's appreciation for coastal resources and awareness of the need for good management. This year, in order to expand into new areas, the MMLS conferred its coordinating role to the Urban Harbors Institute at the University of Massachusetts, Harbor Campus. The

MMLS will complete a manual on how to handle water quality and pollution problems, which will include the legislation and agencies governing the Commonwealth's water resources, and serve as a reference guide to problems, causes, solutions, experts, and bibliographic references. At the request of a member of Sea Grant's National Review Panel, the MMLS will investigate anthropological and sociological constraints on implementation of fishing vessel safety. MMLS personnel also continued to serve as a liaison to the Massachusetts Coastal Zone Management Program and the Massachusetts Bays Program, by serving as chair of the Coastal Resources Advisory Board, and steering committee member of the Citizen's Advisory Committee.

The Communications/Information Service added 33 publications to Sea Grant's report series. A complete collection of these volumes, since 1971 when the series was initiated, is housed in the Information Center, Sea Grant's small marine-related reference library; also on file are Sea Grant reports from the Woods Hole Oceanographic Institution and other members of the Sea Grant network nationwide. A computerized database allows for quick response to information requests from Sea Grant staff, MIT faculty, students, and the public. More than 2,841 reports and other materials were distributed in 1989. Communications also issued press releases, handled media relations and produced the *Quarterly Report* newsletter and the *Citizen's Guide to Sources for Marine and Coastal Information in Massachusetts*. In a new venture, Communications joined with regional Sea Grant programs to produce a biannual magazine, *Nor'easter*, which won silver and bronze awards from the Council for the Advancement and Support of Education. The department also initiated *Current Affairs*, a biannual double-sided handout that served as a tip sheet for many stories printed by the media.

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 applications 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.

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 increase the number of grants awarded through the Undergraduate Research Opportunities Program (UROP). Fourteen UROP awards were given in the fall of 1989, 15 were awarded in the spring of 1990, and seven students were and will be supported in the summer of 1990. The large number of students supported was made possible through generous support by Sea Grant and the Department of Ocean Engineering. Undergraduates for 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 of 1989, Susan Murcott was awarded the honor for her project detailing the circulation and dispersion of effluents from the proposed new South Essex sewage outfall in Salem Sound. Ms. Murcott's project helped clarify the significance of proposed alternative outfall locations. Her project exemplified technical competence, political involvement, public education, and technology transfer. Her activities and local renown led to her being invited to testify before a U.S. Congressional committee.

The 1989 Sea Grant Lecture, "NASA But Not NOAA? Funding for Ocean Research in the 1990s," was given by former Sen. Lowell Weicker. In his speech, Weicker noted that while space exploration was championed by NASA, ocean research has lacked a constituency ready to communicate to Congress the priority of the oceans. Weicker stressed that the research community must take the initiative for pushing funding with individual effort. Proceedings from the 1988 Sea Grant Lecture/Seminar, "Automation in the Design and Manufacture of Large Marine Systems," were also published.

MIT continued its jointly sponsored program of continuing education for New England fishermen with the Massachusetts Maritime Academy and the Commonwealth of Massachusetts.

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 Keith D. Stolzenbach, associate professor in the Department of Civil Engineering. Professor Stolzenbach will be on sabbatical in the coming year. During the interim, his position will be filled by Professor Philip M. Gschwend, who was acting director of the Parsons Laboratory last year. Norman Doelling, who serves as executive officer and oversees the operation of Sea Grant Advisory Services, was promoted to assistant director for Advisory Services and Education. New to the staff was Kathy Seaward, who replaced Susan Stolz Goldie as the information specialist.

MIT Sea Grant administers the Doherty Professorship, endowed by the Henry L. and Grace Doherty Foundation in 1973, for junior faculty at the Institute. In the spring of 1990, Henrik Schmidt, associate professor of ocean engineering, was awarded the two-year chair to conduct research on acoustics. Continuing to hold the appointment is Andrew Whittle, assistant professor in civil engineering, who is conducting research on marine soil strength.

CHRYSSOSTOMOS CHRYSSOSTOMIDIS

Technology and Development Program

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 more 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 activities are initiated on the basis of strong MIT faculty support and willingness to participate. The TDP does not undertake research projects which require large-scale, non-faculty staffing, and all research activities are supervised by faculty members.

The TDP's experience has been that through cooperation among institutions in developed and developing countries, science and technology can be put to more productive use. As a result of such cooperation, both developing and developed countries can reach a better understanding of their own scientific and technological needs.

The Program 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. Committee Members are Professors Moavenzadeh, Daniel M. Holland of the Sloan School of Management, and Jack P. Ruina of the Department of Electrical Engineering.

The TDP-sponsored Middle East Program at MIT completed its fourth 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 field 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 was a new offering which 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

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.

TDP and the Center for International Studies co-sponsored a workshop on "Reconstruction in the Middle East: Challenges of Design and Development". The workshop involved eight distinguished outside speakers and between twenty to twenty-four MIT graduate students, faculty, and research staff members in the presentation and discussion of historical cases of reconstruction and of issues and challenges in current Middle East Reconstruction opportunities.

During the year, Professor Choucri continued her research and examination of patterns of conflict and transformations in the Middle East. Sponsored by the United States Institute for Peace, this project is expected to result in additional interdisciplinary teaching materials on technology and development.

Continuing its work of last year, TDP was successful in establishing an institutional framework and mechanism for a collaborative program on science, technology, and development between the American University of Beirut (AUB) and MIT. These efforts have culminated in the submission of a specific proposal for research and supplementary educational activities that are relevant to the reconstruction of Lebanon and which are expected to be initiated in the 1990 Fall Semester.

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 support research and education at MIT. The TLO staff of 14, seven professionals and seven support personnel, are responsible for identifying marketable technologies, managing their patenting and copyrighting process, finding licensees, and negotiating licenses.

In Fiscal Year (FY) 1990, the TLO received approximately 300 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. Although the percentage of cases for which applications were filed has continued to decline from 64 percent four years ago, the total number of applications filed has continued to increase.

In FY 1990, 102 patents were issued to MIT. Consequently, for the fourth consecutive year, MIT has been granted more patents than any other U.S. university.

Approximately the same number (72) of new license agreements and options were signed in FY 1990 as FY 1989. Four new companies were founded based on MIT licensed technology.

Cash receipts from licenses were \$4.1 million, up from \$3.1 million in FY 1989. In addition to cash, the TLO sometimes receives equity in lieu of up front` licensing fees from newly formed companies. These equity shares are kept in the "TLO Fund" by the Treasurer's Office. The estimated value of the equity for the 21 companies in the TLO Fund increased by almost \$2.0 million to \$6.0 million this year.

The TLO continued a major program to computerize accounting procedures within the office. The ten fold increase in the number of active licenses, together with the three fold increase in income over the last four years made this a particularly high priority. Automated invoicing resulted in both substantially improved collection and timely payment of royalty shares to the inventors. The hire of Nikki Borman for our upgraded financial administrator position contributed substantially to our success in this area.

Our two year plan to improve support to Lincoln Laboratory was completed with the hire of MIT Physics graduate, Lori Pressman '79, as a licensing officer. Ms. Pressman's strong industrial background in optics, electronics and lasers, together with the reestablishment of a TLO office at Lincoln, has brought the level of TLO support to Lincoln Laboratory to a level commensurate with that provided to departments and laboratories on campus. In addition, together with Lincoln, the TLO has been instrumental in initiating Technology Transfer Agreements and Collaborative Research Agreements to foster and improve the transfer of technology developed for the US Government to the industrial sector.

JOHN T. PRESTON

Whitaker College of Health Sciences and Technology

The Whitaker College of Health Sciences and Technology (Whitaker College) has evolved into a major interdisciplinary academic and research entity at MIT. Since 1983, we have continued to develop and incorporate areas of research and teaching that are pertinent to health and range from the fundamental to the applied.

Activity in the Whitaker College is divided among the Department of Brain and Cognitive Sciences, the Clinical Research Center, the Division of Toxicology, the Center for Environmental Health Sciences, and several interdisciplinary programs which are administered directly by the College headquarters.

I am pleased to 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

Programs in bioengineering focus on (1) biological and medical imaging, including radiological sciences, and (2) medicinal chemistry and drug delivery systems.

Biological and Medical Imaging

The Whitaker College Biomedical Imaging Laboratory (Biomedical Imaging Laboratory) was established in 1988 to serve as a nucleus and base for medical and biomedical imaging research activities within the MIT community. The laboratory is now equipped with eight state-of-the-art SUN workstations, several peripherals, and the facilities to convert microscopic images to digital form. In addition to providing a site for the primary faculty associated with this effort, the goal of the laboratory is to encourage the participation of faculty, research staff, and students in relevant departments to collaborate on basic research in imaging technologies and in image processing and display methods.

Under the direction of Professor Derek Rowell of the Department of Mechanical Engineering, research activities this year have included 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 standard resource for image processing. Applications have included topics in cardiology, biomechanics, blood flow, magnetic resonance imaging (MRI), three-dimensional reconstruction, and positron emission tomography (PET) imaging. In addition, several Monte Carlo simulation methods for modeling radiation transport in nuclear medicine imaging and in radiation therapy have been implemented.

These computational tools have been used extensively for research as well as teaching in the Nuclear Engineering Department. The Biomedical Imaging Laboratory was also used as a teaching laboratory for the Division of Health Sciences and Technology (HST) Signal Processing course, offered in the spring of 1990. The laboratory projects were designed to provide practical experience in processing physiological data with examples from neurophysiology, cardiology, and two dimensional image analysis.

This year I convened a group of interested faculty and senior researchers representing the Department of Mechanical Engineering, the Department of Nuclear Engineering, the Division of Health Sciences and Technology, and the Francis Bitter National Magnet Laboratory to consider the long term mission of biomedical imaging research at MIT. We have met on a regular basis to consider means by which the College can enhance MIT's ability to contribute to the field of biomedical imaging. One result of these meetings

was the initiation of a Biomedical Imaging Sciences lecture series. Sponsored by the Whitaker College and coordinated by Professor Jacquelyn Yanch, three nationally renowned scholars were invited to present topics in the field of imaging. I am pleased to report that the lectures were well received with attendance and enthusiasm from both MIT and related imaging centers in the Boston area. Plans are underway to continue the series next year.

Radiological Sciences

Professor Gordon L. Brownell, who holds a primary appointment in the Department of Nuclear Engineering, has been a principal force in the development of education and research in radiological sciences in the Whitaker College. This year, he chaired a committee that has made recommendations to strengthen the relationship of the program with the Division of Health Sciences and Technology and has agreed to act as Principal Investigator in the re-submission of a graduate training grant.

In research, Professor Brownell together with Professor Jacquelyn Yanch began a three year study funded by the Department of Energy to develop an accelerator source of epithermal neutrons for neutron capture therapy. The accelerator is being built by the Science Research Laboratory while the moderator, reflector, filtering, and shielding will be designed by Professors Brownell and Yanch in the Biomedical Imaging Laboratory. The preliminary design calculations have been completed. One full length paper and two abstracts (submitted to an international meeting to be held in December, 1990) have come from this project.

In other areas, Professor Brownell has continued his research into high resolution positron emission tomography (PET) systems, specifically the construction of a high resolution volume-sensitive positron imaging device (PCR-II). An analysis of the limitations of PET imaging has been undertaken in doctoral thesis research by one of Professor Brownell's four graduate students.

Professor Jacquelyn Yanch was appointed as Assistant Professor in the Department of Nuclear Engineering, effective July 1, 1990. She holds a joint secondary appointment in the Whitaker College, where much of her research activity is based. In addition to her collaboration with Professor Brownell, she has been working with two graduate students on the use of computer simulation in Single Photon Emission Computed Tomography (SPECT).

Experimental verification of Monte Carlo generated results has been set up with the New England Medical Center in Boston. Supported primarily by a Biomedical Research Support Grant, Professor Yanch was recently awarded a pilot research grant from the Society of Nuclear Medicine to provide additional support for this work.

In another study, the dosimetry involved in treating brain tumors with Californium - 252 implanted needles was investigated by Monte Carlo simulation. This work was carried out in the Biomedical Imaging Laboratory and the results were presented at a national workshop on neutron therapy in May. Dosimetric study was also carried out on the use of beta-emitters in the treatment of rheumatoid arthritis. This work has been funded for an initial one year period by the Whitaker Health Sciences Fund. This year Professor Yanch supervised four graduate students.

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.

This year has been very productive. A drug delivery system using biodegradable polymers and developed by Professor Langer's group is now being used in the treatment of over one 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 chondrocytes or 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 and in vitro have show that a novel immobilized enzyme reactor can remove cholesterol five times faster than normal. Finally, Professor Langer and his laboratory have purified and sequenced a substance from cartilage that causes inhibition of neovascularization.

Active in teaching both semesters, Professor Langer and his colleagues also presented a one week summer course in Controlled Drug Delivery Systems. He supervised fifteen 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, ten postdoctorals, two visiting scientists, and five research staff.

Professor Langer, who holds a secondary appointment in the Whitaker College which houses his major laboratories, has a primary appointment in the Department of Chemical Engineering.

PROGRAM IN HEALTH POLICY MANAGEMENT

The Health Policy and Management Program is projected to terminate in January 1991, with the completion of the degree programs of the three students currently enrolled. Three other students were awarded the Ph.D. in June, 1990.

The Program offered an MIT Special Summer Program entitled "Managing the Quality of Health Care" for the second time during the summer of 1989. The course was again very well received.

FACULTY AND STAFF

Professor Robert Langer was named to the Kenneth J. Germeshausen Professorship. He has also been the recipient of several awards this year including the Professional Progress Award from the American Institute of Chemical Engineers, The Clemson Award for Basic Research from the Society of Biomaterials, and the Creative Polymer Chemistry Award from the American Chemical Society. The American Chemical Society sponsored a three day meeting in his honor in April of 1990.

Professor Yanch was named the first recipient of the Class of 1958 Assistant Professorship Chair. She will hold this chair for three years through 1992.

KENNETH A. SMITH
DIRECTOR

Department of Brain and Cognitive Sciences

Research in the Department of Brain and Cognitive Sciences 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.

Cognitive Neuroscience

This year, the McDonnell-Pew Foundation awarded a grant to the Department for the formation of a Center for Cognitive Neuroscience. The principal focus will be 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 will facilitate collaborative work among faculty who are engaged in pioneering work in their respective areas.

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 twenty percent. Fellowships are supported by a variety of sponsors, both federal and private.

Two new foundation awards to the Department are enabling us to establish departmental fellowship programs: The Department's Program in Cognitive Neuroscience, established this spring with the support of the McDonnell-Pew Foundation, sponsors five fellowships. The goal of this program is to train scientists adept at the disciplines and techniques of neuroscience, computational neuroscience and cognitive science. Additional fellowships in the area of Neurobiology will be awarded next year with the financial support of the Markey Charitable Trust.

Graduate

Nine students received Ph.D.s during the year, and each went on to an excellent postdoctoral or junior faculty position. The number of applications to the program continues to increase. We are pleased that new predoctoral fellowships will soon be made available from the Markey Foundation and from the McDonnell-Pew Center for Cognitive Neuroscience, and we continue to seek additional sources of support.

Under the auspices of the McDonnell-Pew Center mentioned above, we have created a new Ph.D. training track in cognitive neuroscience. In the spirit of the Center's dedication to multidisciplinary approaches to the study of higher brain function, students will be co-advised by faculty members from two of the three fields of systems neuroscience, computational neuroscience, and cognitive science, and thesis projects will contain elements of investigation from both fields. New laboratory courses in computational modeling, design and interpretation in cognitive psychology, and cortical function will be added to the curriculum.

Another initiative has been taken in the signing of an agreement with the International School of Advanced Studies in Trieste, Italy. The goal of the new program is to train scientists who will later comprise the staff of a new unit of ISAS, to be known as the Institute of Intelligent Systems, dedicated to research in the interdisciplinary study of the brain and the modeling of its functions. This program gets underway with the arrival of two special graduate students in September 1990.

Undergraduate

The undergraduate major in cognitive science was revised during the academic year 1989-90 in an effort to bring greater mathematical and formal rigor to the major without losing sight of the diversity of interests that animates students of cognitive science. Enrollment in Course IX remains steady, with 41 primary majors as of September 1989.

Our participation in the Program in Psychology has continued, and our already extensive participation in the UROP program has almost doubled. Undergraduate enrollment from these sources has continued to rise steadily.

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.

Awards:

Christopher Atkeson - Graduate Student Council Departmental Teaching Award
in Course 9 (1989-90)
Mriganka Sur - Graduate Student Council Teaching Award 1989

New National Academy Member:

Mary Potter - Fellow American Psychological Association

Special Appointments:

Hermann Steller - Howard Hughes Medical Institute Assistant Investigator
Richard Held - Chair, Behavior, Performance, and Human Factors Discipline
Working Group of NASA
Bunting Institute Review Committee
NAS/NRC Committee on Wraparound Visual Displays (analysis of
visual problems related to defense
NEI Internal Review Committee
Bunting Institute Review Committee, Harvard University

Invited Speakers:

Richard Andersen - XXXI International Congress of Physiological Sciences,
Helsinki, Finland, 7/89
25th Anniversary of the Brain Institute, Zurich,
Switzerland, 11/89
International Symposium on Brain & Space, Marseilles,
France, 11/89
Society for Neuroscience, Arizona, 11/89
Keynote Address for the Australian Conference on Neural
Networks, Sydney, Australia, 1/90

Mcknight Foundation Semi-annual Meeting, 3/90
Keynote Address for the German Neurobiology Meeting,
Goettingen, FRG, 6/90
Session Chair, International Joint Conference on Neural
Networks, San Diego, CA, 6/90
Session Chair, Functional Mapping of the Human Brain
Workshop, Johns Hopkins Univ., 6/90

- Richard Held - Aga Khan Program
Colsten Lecturer, Bristol England
Garrett Lecturer, Joint Franklin-Marshall & Lancaster
Ophthalmological Association lectures
Santa Barbara Conference on Telerobotics and Virtual Worlds
Homage to Hans Wallach
Yakult Symposium, Tokyo
ATR, Nara, Japan
Tokyo University, Komaba
- Michael Jordan - Tokyo Symposium on Biological Complexity, 1989
Conference of the American Association of Artificial
Intelligence, 1989
- Mriganka Sur - Oxford University, August 1989
Max Planck Institute for Brain Research, 8/89
Retina Research Foundation, May 1990
International School of biophysics, Erice-Sicily, June 1990
- Richard Wurtman - Wellcome Visiting Professor, Washington State University,
1989
Alan Rothbalier Memorial Lecture in the Neurosciences (NY
Medical College), Fall 1989

EMILIO BIZZI, M.D.
Chairman

Center for Environmental Health Sciences

MAJOR ADVANCES

Analysis of the water of the nearby Aberjona River and its tributaries has revealed no detectable bacterial or human cell mutagens. Sediments of these streams, however, are giving strong signals in bacterial assays and chemical analysis is being coupled with genetic analysis to identify the mutagen(s) responsible for these observations. (H. Hemond and P.M. Gschwend, Civil Engineering).

The use of laser-induced fluorescence spectrometry at cryogenic temperatures has permitted direct measurement and identification of hemoglobin reaction products with pyrene-containing polycyclic aromatic hydrocarbons. This group of chemicals enters humans via smoking, inhalation of air-borne particulates and ingestion of high temperature cooked foods. For the first time, human exposure to these ubiquitous and genetically active agents may be directly assessed. (S.R. Tannenbaum and R.R. Dasari).

Using the multicopy mitochondrial genome and the new technology of mutational spectrometry, it has become possible to measure the set of genetic mutations directly in a small (0.1 ml) blood sample. Studies of the actual kinds of genetic changes arising in MIT graduate students are in progress. (W.G. Thilly and P. Keohavong).

Goals and Direction

The Center for Environmental Health Sciences at MIT aims to bring together those parts of established disciplines which are, or should be, focused on discovering which ordinary interactions between humans and chemicals, biologicals or radiation, are in fact harmful to health. It is a basic tenet of our field that, given accurate knowledge of the nature and extent of harm associated with exposures to identified substances, individuals may make informed choices for themselves and societies may make choices for the health of the general public, particularly the young.

The faculty, students, and research staff of MIT's Center for Environmental Health Sciences are focused on discovery of the agents in our environment responsible for genetic changes in humans. Our focus is based on our perception of the public health needs. Genetic disease causing severe physical or mental impairment of our newborns approaches 2%, and fills nearly half of the beds in our pediatric hospitals. Human cancers require several genetic changes (mutations) inherited or occurring within the organ from which the tumor arises. It seems very probable that atherosclerosis - a colonization of arterial walls with descendants of a single aberrant ancestor - requires specific mutations.

The Genetic / Environmental Interaction

Given that genetic change is required to cause these diseases, we have undertaken the research programs necessary to discover the general causes of genetic change. We will also be required to find the causes of very specific genetic changes causing particular diseases. In this effort, we are linked to the earliest efforts in genetics. Indeed, the concept of a gene as a quantum unit of life was to a great extent clarified by Muller's observation that x-rays caused stable changes (mutations) in fruit flies. Max Delbruck, one of the principal intellects in the establishment of quantitative biology, used the early dose-response relationship between fruit fly mutation and x-radiation in order to calculate-correctly it seems-that cosmic rays were not a significant contributor to the rate of spontaneous genetic change (in fruit flies).

After the identification of x-rays as mutagens, ultraviolet light and then reactive chemicals were found to cause genetic changes in fruit flies, bacteria, and bacterial viruses. We came to see the world we live in as a complex mixture of chemicals, radiation, and bits of genetic material impacting on humans through the everyday processes of eating, drinking, and breathing. Smoking, narcotic and alcohol abuse, and medicinal treatment are a part of that reality. Exposure can occur for a small number of people in a particular occupation or to millions of people sharing the air in a particular city.

The Center As A Collaboration

The Center is a consortium of faculty with special knowledge of food chemistry, combustion, incineration and air pollution, hazardous waste storage and environmental movement in water supplies, toxicologists and analytical chemists. We have identified the chemicals principally responsible for causing the genetic changes observed when bacteria or human cells are exposed to certain food or soot extracts. We have mustered the collective will and developed the necessary technology to discover by iterative experimentation the principle causes of the mutagenicity of any complex mixture. This form of collaborative research and its contribution to knowledge has been one of our Center's most important accomplishments. Significantly, we have directed attention away from the search for "most active mutagen" and focused it on the search for "most important mutagen". This product of environmental concentration and specific mutagenic activity is used to set both research and remediation priorities.

Combustion As A Source Of Environmental Mutagens

A good example of the application of this concept has been the identification of the most important mutagens generated by fossil-fuel combustion products. We collected combustion products generated by a variety of devices which burn fossil fuels, identified the kinds and amounts of chemicals in the emissions, and conducted bacterial and human cell mutation assays on the products. This comprehensive approach has provided the data necessary to understand the chemical and physical mechanisms by which mutagens are synthesized in combustors, the chemical identification of the mutagens of concern, and the definition of the conditions required for their destruction.

The Center has built well established combustion research efforts in the Chemical Engineering Department involving Professors Beer, Howard, Longwell, Sarofim and Tester. A large number of combustion facilities are available, ranging from low-pressure small flames used to identify key combustion intermediates, to a well-instrumented pilot-scale three megawatt thermal combustion facility. Fuels studied include natural gas, petroleum distillates, coal, shale-oil, and solvent-refined coal, as well as pure compounds such as benzene and ethylene which are used to unravel the complex mechanisms of the pyrosynthesis of mutagens.

The interdisciplinary study produced several results that ran contrary to our collective expectations. Fluoranthene and cyclopenta [c,d] pyrene were found to be more important mutagens for bacterial and human cells than benzo [a] pyrene because of their much higher concentration in combustion products. Also, the concentrations of soot and polycyclic aromatics were often poorly related. A burner adjusted to eliminate visible smoke could well produce a higher concentration of mutagens than if it were adjusted to produce smoke! Our attention has now turned toward aromatic compounds containing oxygen and/or nitrogen. Phenalene-one, for example, is found to contribute to mutagenicity in effluents of a home heating furnace. Heterocyclic compounds are present in the combustion products of other fuels as a consequence of

the emissions of residues of moieties present in solid fuels such as coal and wood or their formation *ab initio* in the cooler zones of a furnace. The chemistry of such systems is complex, but we have the means to dissect the major sources and paths of mutagen formation.

Human Variation And Confident Extrapolation

Of course, every concept has its limitations. Our discoveries of important mutagens and carcinogens in ordinary environmental mixtures were limited in practical public health value by the fact that our laboratory test systems - bacteria, human cells, and rodents - were not people. We know that when a chemical enters the body, a complex cascade of series and parallel chemical reactions ensues. The reactions lead to innocuous excretion or potentially mutagenic reaction with the genetic material, DNA. The number of catalysts - enzymes - involved in these cascades is large enough and evolutionary time so great that the dynamics of these cascades in tissues of different species are, in general, non-identical and frequently grossly different. Within a particular human the dynamics of this cascade - usually called drug metabolism - varies significantly among the various organs. This diversity prevents confident extrapolation of the genetic effects of a chemical from one species to another or from one tissue to another. Furthermore, the field of pharmacogenetics has established the fact that among non-inbred species, such as humans, the range of drug metabolism capability is so large that one cannot meaningfully speak of "human" drug metabolizing unless one has characterized a sufficiently large number of individuals. This fact is well known in pharmaceutical development in which adverse effects of drugs on several percent of patients has been linked to marked deviation from average behavior in drug metabolism.

The Failure Of DNA Repair And Hereditary Change

A second complex cascade of biological reactions separates the DNA reaction products from the stable genetic change itself. This cascade is known as "DNA repair" and consists of enzymes cutting out abnormal reaction products and restoring the DNA to its original sequence. It is the failure of the DNA repair system to act before DNA replication is required or the introduction of the wrong DNA sequence in the repair process that ultimately leads to hereditary change after a cell is treated with a mutagen. As in the case of drug metabolism, the processes of DNA repair involve many different genes; diversity among species is the rule and variation among tissues and humans in the population occurs to an important extent.

The Aberjona Basin

Progress in the analysis of environmental chemicals reaction products with proteins or DNA, and analytical genetics of human tissue samples now leads us to epidemiological studies to find out what chemicals are present and which ones are causing genetic damage in ordinary citizens.

To prepare the way for intelligent application of the new technology, the faculty of the Parsons Laboratory for Water Resources and Hydrogeology have begun a major study of the fate and transport of chemicals in the nearby Aberjona River Basin. Already in progress is a chemical reconnaissance in the Basin, characterizing the nature and amounts of chemicals in local ground and surface waters. The Aberjona Basin is home to some 50,000 people, including many faculty and research staff and their families, and has been since precolonial times the site of industries such as tanning and bulk chemical production that involved release or storage of large amounts of chemicals now known to have the potential to cause genetic damage.

This Aberjona Basin Study involves a large portion of the Department of Civil Engineering's Parsons Laboratory faculty. The need for careful macro-and microscale modeling of mass transfer within the basin is required for both water-and air-borne chemicals. Working out the population exposure patterns will take some few years, which is consonant with our expectation of the time needed to be ready to use the direct human measurement technology.

Of course, knowledge of air and water exposure must be factored with food and drug exposure to create a complete picture of human exposure. We hope to bring our methods to bear on population studies in our own communities without prejudice as to what we may find. Other epidemiological efforts less catholic in scope are already in progress. Studies of smokers, persons exposed to high concentrations of therapeutic drugs or markedly high levels of dietary mycotoxins are coordinated with studies in experimental animals and cell cultures.

Building A New Paradigm

The substantial variations among species and among humans in drug metabolism and DNA repair obliges us to conceive of an approach which does not depend on either species extrapolation or the statistical mean of human populations. Put simply, a person is expected to suffer significant genetic damage from the environmental agents to which he or she exposed if, and only if, his or her particular pattern of drug metabolism and DNA repair permits such damage. Since we eat, drink, and breathe tens of thousands of potential mutagens each day, there exist no real means to use non-human systems with confidence in predicting absolute or relative human genetic risk arising from exposure to a particular compound.

Now that this hard truth has been faced, Center faculty are in a position to work together to build a new intellectual paradigm and to develop the technology to apply it to human studies.

Our new paradigm consists of three questions:

(1) What are the chemicals which enter the human body which can themselves or through metabolites react with genetic material?

We accept as axiomatic that chemicals that do not enter the human body will not cause genetic harm. If we knew which chemicals were reacting with people's DNA, we could focus on them to discover if they are causing significant genetic damage.

Unfortunately, we do not yet have analytical means to identify and measure the reaction products with DNA in convenient and safe human samples such as one to ten milliliters of blood. .

However, chemical reactions with DNA are mimicked to a reasonable extent by reactions with the blood proteins such as hemoglobin. The quantity of hemoglobin adducts has been sufficient to allow Professor Tannenbaum's group to develop a new technology to measure any of the series of amino or nitro-aromatic compounds. This work has provided us with the first quantitative picture of a whole class of environmental chemicals in people. Present work focuses on developing the means to measure hemoglobin adducts of the polycyclic aromatic hydrocarbons.

The next major step needed is to be able to measure and identify hemoglobin adducts of unknown structure. Professor Klaus Biemann's projects are aimed at this goal. The process involves fundamental changes in the hardware of mass spectrometers.

In related work, Professor Gerald Wogan's lab is exploring means of interfacing separation technology with the mass spectrometric developments so that DNA adducts may themselves be directly measured and identified.

(2) Of the chemicals found in ordinary humans, which, if any, cause significant amounts of genetic change?

Given knowledge of the set of chemicals bound to a particular person's hemoglobin, it does not seem unreasonable to hypothesize that one or a few of these chemicals have been the principal causes of mutations in the same body compartment. Thus, the analysis of chemical adducts "accuses" suspects for the analytical geneticists to "interrogate".

The interrogation involves applying a process under development for obtaining the mutational spectrum of white blood cells from the individual studied for each accused chemical. The mutational spectrum is the distribution of all mutations in a particular DNA sequence with regard to kind and position of mutation. The mutational spectrum from the donor sample could be compared to the spectra induced by the accused chemicals. The process is similar to using fingerprints in identification. When match is made, there would be strong circumstantial evidence that the chemical found in the donor's blood proteins had been responsible for a significant amount of genetic change in the donor's blood cells.

An important point is that each person serves as his or her own control in such studies. The large interpersonal variations expected in drug metabolism and DNA repair should not, therefore, interfere with this proposed diagnostic process.

(3) Which chemicals are significantly contributing to the genetic changes leading to human disease such as cancer?

Certain mutations specific both for kind and position are now known to be necessary for genetic activation of the ras cancer genes in humans and experimental animals. Based on the recent work by Penn showing that a small fraction of DNA of human atherosclerotic plaque can cause a form of neoplastic transformation of rodent cells, it seems reasonable to consider the possibility that there exists one or more genes that follow analogous genetic pathways in this important disease state.

The work of Professor Gerald Wogan's laboratory has focused on the set of such mutations appearing in liver tumors in rats after aflatoxin treatment. Further knowledge of the set of similar, specifically-required genetic changes in all human tissues at risk will be required to devise means to identify the exogenous chemical mutagens that might, in the case of studying individual humans, induce these specific onco-mutations.

Professor Helmut Zarbl is studying the network of physiologic effects of oncogene mutation, and aims to uncover additional loci which must be considered at risk for mutation by environmental chemicals. A key set of his experiments now in progress aims at discovering whether carcinogens causing organ-specific tumors with specific ras mutations act by causing the mutation or selecting for cells in which the specific mutation already exists.

Mutagenesis And The Context Of DNA Sequence

It follows from this discussion that the set of chemicals causing most of the total genetic changes in a particular human need not necessarily include the chemicals that

induce tissue-specific tumors or atherosclerotic plaque. Indeed, the very existence of mutational spectra teaches us that we must examine the effect of a chemical mutagen within the context of a particular DNA sequence within the chromatin. Further, other evidence indicates that, within a tissue, one will have to consider variables such as the degree of transcription of a gene or the cell's proliferative state in defining the mutational spectrum for any mutagen.

The group of interacting scientists who consider these variables are organized in a program aiming at dissecting the molecular steps in mutagenesis. This group, with faculty in MIT's Division of Toxicology, Departments of Biology and Chemistry, Harvard University's Department of Biochemistry and Molecular Biology and the School of Public Health, considers the molecular pathways of genetic change in bacteria, yeast, rodent, and human cells.

Reaching A Better Understanding: Our Health And The Environment

Surely this is an exciting time for analytical chemistry, genetics, and oncology, for the means to carry our studies to the human body are within our reach. And yet, the process of developing a new paradigm for human studies requires special care to be sure that early observations are not inappropriately interpreted. We foresee a period in which the best of us must remain determinedly agnostic, focusing always on our responsibility to discover what interactions between us and our environment are in fact harmful to health.

WILLIAM G. THILLY

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 MIT did not, and still does not, administer a regular teaching hospital to which its CRC might be attached, 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 two years ago it was incorporated within the Whitaker College, reporting to the Director of Whitaker College and Associate Provost, Professor Kenneth Smith, who is also the Principal Investigator of the CRC's NIH grant.

Scientists and physicians authorized to carry out research protocols using the CRC's facilities, once these protocols have been approved by MIT's Committee on the Use of Experimental Subjects (COUHES) and the CRC Advisory Committee, 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.

The CRC is administered by a Director (Professor Richard J. Wurtman), an Associate Director (Dr. 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).

The CRC Advisory Committee, consisting of 12 voting members plus five non-voting members of the CRC's Program Staff, reports to the Principal Investigator, Dr. Kenneth Smith. The Committee meets 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. It has not previously been necessary for the Advisory Committee to prioritize protocols since - with careful scheduling - adequate resources have usually been available to implement all approved protocols. However, such prioritization may become necessary in the future.

For the time period July 1989 - June 1990 utilization at the CRC totaled 553 inpatient days and there were a total of 4579 visits to the CRC's outpatient facilities.

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 1989-90 there was one graduate student and 14 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.

In March, 1990, the CRC sponsored a half-day symposium on "Energy Metabolism". The speakers were:

- Elliot Berry, M.D. "Regulation of Body Shape and Body Weight"
- Susan Roberts, Ph.D. "Energy Metabolism and the Development of Obesity: New Techniques for Assessment"
- Richard Galbraith, M.D., Ph.D. "Synthetic Metal Porphyrins: Appetite and Body Weight"

Joint Commissions on the Accreditation of Healthcare Organizations

In January 1988, in response to an NIH mandate, the CRC started the process of applying for JCAHO certification, and was notified soon thereafter that, given the scope of its activities, the JCAHO chose to examine it as an ambulatory care facility. After a nine-month period of preparation, during which By-laws were written, a new committee structure established, and formal quality assurance mechanisms developed, the CRC was examined on June 20-21, 1988. Based on that examination, it was awarded accreditation as an ambulatory care unit in September, 1988.

Medical Department Merger

Since the JCAHO accreditation as an ambulatory care facility was not considered adequate by the GCRC branch of the National Institutes of Health in review of evolving guidelines requiring that NIH-funded CRC's be certified as hospitals, discussions were initiated with MIT's Medical Department leading, on October 3, 1989, to the decision of all parties that the CRC be incorporated within that department, which is a JCAHO-accredited hospital. This incorporation took place on February 1, 1989, and has conferred JCAHO accreditation as a hospital upon the CRC. Association with the Medical Department will allow the CRC to approve protocols which involve acutely ill or potentially unstable patients.

All CRC outpatient activities are still conducted at the current CRC facility. CRC inpatients are admitted to and sleep at the Medical Department infirmary. Depending on the protocol, some inpatients spend all of the day hours at the CRC participating in protocol activities and resting in the CRC day rooms and lounges, while others are transported to the CRC for protocol activities but are then taken back to the Medical Department. Inpatients take meals at the CRC on weekdays and have meals provided at the Medical Department by the CRC kitchen on weekends. Outpatients receiving meals are served in the CRC.

In summary, the CRC presently has a dual administrative locus within MIT: As a patient-care unit, the CRC is a part of MIT's Medical Department, and all CRC committees and functions concerned with patient care and quality assurance report to the Medical Department or have been incorporated within the Medical Department's own system. However, as a research unit the CRC remains a part of MIT's Whitaker College, and all committees and functions concerned with its use for actualizing research protocols (e.g.,

the Advisory Committee) or providing training report to the CRC's Principal Investigator, Kenneth Smith, the MIT Vice-President who is responsible for the Whitaker College.

Core Laboratory

The change in function of the Core Laboratory from that of earlier routine screening to research analyses that support multiple protocols has now been completed. The HPLC system for amino acid analysis has been in full operation and also is now used routinely to measure physiologic amino acid profiles in plasma samples. The plasma tryptophan assay by spectrophotofluorometry has been utilized extensively by investigators and will now be routinely determined for our clinical protocols. The laboratory also routinely performs multiple radioimmunoassays for hormones. New micro methods for plasma free fatty acids, plasma triglycerides, and for glucose were set up in 1988 and these have been utilized since then. Although these assays are available via the clinical laboratory, the laboratory performs them when sample sizes are limited due to blood drawing restrictions.

A major, further change in the Core Laboratory, which has proceeded very well, concerns the establishment of the capability to undertake isotope ratio (IR), and/or gas chromatograph (GC), mass spectrometric (MS) analysis. The GCMS system was installed in March, 1987, and is routinely operating for purposes of analysis of ^{13}C , ^2H and ^{15}N amino acids. Further methodological developments are underway to service the GC/MS needs of the various clinical protocols. The IR/MS is making routine determinations of ^{13}C enrichment in expired air. Method development is underway to achieve the capability for routine analysis of ^{18}O , HD and ^{15}N . One of the Core Laboratory technicians is now receiving training in the conduct of GC/MS determinations.

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 hormones secretion; studies on a set of diseases characterized by affective and appetitive symptoms (i.e., depression, carbohydrate craving, and weight gain and/or 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.

Nutrition Metabolism

During the past year the Nutrition and Metabolism group directed by Professor Vernon R. Young has continued to explore the regulation of whole body methionine metabolism with the aid of [$^2\text{H}_2$ -methyl- $1\text{-}^{13}\text{C}$]methionine as a stable isotope tracer. A study has been completed on the effects of a dietary supplement of betaine (3g per day) on methionine kinetics in order to begin to understand the metabolic basis for the therapeutic effects of betaine in patients with cystathionine synthase deficiency. Betaine was found to increase rates of methionine transmethylation and oxidation, particularly when the methionine tracer was given orally together with the betaine supplement. Thus, homocysteine remethylation and subsequent oxidation of the methyl group of methionine via the transsulfuration pathway is stimulated by addition of betaine to the diet. These findings support the concept that the lowering of plasma homocysteine, in patients with cystathionine synthase deficiency, by betaine, is due to an enhanced rate of homocysteine oxidation. They also suggest that an excess intake of methyl groups may increase the dietary requirement for methionine.

From an extensive series of stable isotope tracer metabolic studies carried out at the MIT CRC over the past six years Dr. Young and his associate investigators have concluded that adult human requirements for specific nutritionally indispensable (essential) amino acids are considerably higher than current international recommendations. To further explore the possible basis for the discrepancy between the isotopically derived estimates of requirements and those that were generated from earlier metabolic nitrogen balance studies two investigations were conducted to examine whether metabolic interactions among the branched-chain amino acids occurred, so complicating the determination of the requirements for leucine or valine. From the findings of leucine or valine oxidation at varying intakes and proportions of leucine and valine it is concluded that, within a physiological range, there are no significant metabolic interactions that confound the determination of the requirements for these two amino acids. Hence, the proposed new and higher values of the minimum physiological requirements for amino acids in healthy adults appear to be valid.

In continued work examining the impact of age on nutritional status and requirements and nutrient utilization in man, Dr. Naomi Fukagawa has recently completed a study focused on the relationship between fat-free mass (FFM) and metabolic rate in young (18 - 33 years) and old (67 - 75 years) individuals. Results demonstrate that differences in FFM cannot fully account for lower metabolic rates in the old, suggesting that aging is associated with an alteration in tissue energy metabolism. This is contrary to the generally accepted premise that age-related alterations in body composition are responsible for differences in energy requirements. In addition, a systematic comparison of different methods for assessing body composition in the elderly suggested that anthropometry is not adequate to assess group differences in body fatness although skinfold measures may be appropriate for within group comparisons. Moreover, bioelectric impedance analysis correlates well with the isotope dilution technique for body composition in both age groups. These findings raise important considerations in studies of the aging population and challenge preconceived notions about the basis for age-related changes in nutrient requirements.

Obesity

Dr. William Dietz and his associates conducted a study of obese subjects with low energy intakes. They studied a group of obese children and adolescents with reportedly low energy intakes. Resting metabolic rate was measured by indirect calorimetry and body composition by bioelectrical impedance. To date, energy expenditure in these subjects does not differ significantly from that in normal controls. The reported discrepancy between energy intake and energy expenditure must be attributable to inaccurate dietary intakes provided by parents and children, and provides an initial focus for therapy.

In a prospective study of adolescent growth and development, Dr. Dietz and his associates have developed an exercise protocol for the measurement of maximal oxygen consumption in pre-adolescent girls. They have begun preliminary testing in a few girls to test the usefulness and practicality of this protocol.

In addition, they are currently modifying their existing metabolic cart for the measurement of resting metabolic rate to improve the sensitivity of the measurement. They have added a pressure transducer for the on-line measurement of flow as well as a humidity device to determine water vapor accuracy of the flow measurement. They have replaced the Apple 2E computer with an IBM PC to allow them to further improve the data acquisition, data storage and data management of this system. The software is currently being written to accommodate the changes in flow and the new data acquisition system.

Questionnaires on physical activity have been developed and piloted on a sample of girls. A diet diary has also been developed for the use of obtaining fourteen-day food records. Contact has been made with the Cambridge School Board for the recruitment of subjects and procedures are being developed to facilitate this collaboration.

Behavioral Neuroscience

The Behavioral Neuroscience Laboratory under the direction of Professor Corkin and her associates with the collaboration of Dr. John H. Growdon continues to pursue a program of research seeking dissociations of cognitive, sensory, and motor functions in patients with neurological disease. Dissociations exist when one patient group performs a particular kind of task normally but is impaired in others, while another patient group shows the opposite pattern of performance. Their goal is to identify the neural substrate for different behavioral capacities. The groups that they have studied include chronic global amnesia, head injury, Alzheimer's disease (AD), and related dementias, Parkinson's disease (PD), progressive supranuclear palsy, and age-matched healthy control subjects. Some of their findings are:

- 1.) Prior research demonstrated that veterans of World War II with penetrating head injury (HI) incurred in young adulthood showed exacerbated cognitive decline in later years relative to World War II veterans with peripheral nerve injury [Corkin, et al., 1989]. Older HI subjects experienced greater decline than younger subjects on a test measuring overall intelligence and on a test measuring spatial abilities. The present paper used multivariate analyses of the HI subjects' data ($N = 57$) to determine whether the correlations between age and decline reflected age at injury (range 18 to 33 years) or age at follow-up testing (range 54 to 72 years). The results indicated that both age variables predict cognitive decline.

The observed absence of a correlation between test-retest interval (range 25 to 33 years) and cognitive decline suggest that decline resulted from aging processes rather than the mere passage of time. Two derived age variables (the mean of a subject's two ages, and the difference between them) independently predicted the decline of AGCT Total scores and the Block Counting subtest of the AGCT. Subjects with

shorter spans from injury to 1980s testing declined more than subjects with longer spans; we interpret the association as implying that cognitive decline in later years increased as a function of age at injury. Older subjects declined more than younger subjects, implying that cognitive capacities declined as an accelerated function of age.

2.) Visual deficits were observed in patients with Alzheimer's disease (AD) relative to age-matched and to young healthy control subjects in the following functions: color; stereoacuity, contrast sensitivity, and backward masking (homogeneous and pattern). Critical flicker thresholds were normal relative to age-matched healthy subjects. For color, the majority of the errors were tritanomalous (blue axis). Color and stereoacuity deficits were unrelated to dementia severity, in accordance with models of vision that describe these functions as modular rather than diffuse for cortical localization. Although contrast sensitivity was depressed throughout the frequency range in AD, more patients were impaired at low than high spatial frequencies, contrasting with the observed normal aging pattern of high frequency loss. Healthy elderly subjects showed depressed critical flicker fusion thresholds and reduced contrast sensitivity at high frequencies relative to the young group; differences between these groups were not found for the other vision tests. A subset of the AD group received detailed neuro-ophthalmological examination, and no abnormalities were found. This finding, taken together with normal thresholds for critical flicker fusion, suggests that the widespread visual dysfunction reported here is more likely to be related to known pathological changes in primary visual and association cortex in AD than to changes in the retina or optic nerve.

Neurochemistry - Psychopharmacology

1.) In the treatment of Seasonal Affective Disorder Syndrome (SAD) Dr. Judith Wurtman, Dr. Dermot O'Rourke and their associates demonstrated that patients with this form of annual atypical depression responded therapeutically to a drug, d-fenfluramine, that selectively enhances serotonin-mediated neurotransmission (i.e., by both releasing the transmitter and suppressing its presynaptic re-uptake). The d-fenfluramine ameliorated both the affective and appetitive symptoms: it lowered Hamilton Depression Scores (and the supplemental scale used to assess atypical depressions) to normal levels, and blocked both the enhanced food intake (and winter weight gain) and the carbohydrate-craving associated with this disease. In follow-up studies it was shown that the drug continues to work at unchanged daily dosages, for the three month period which usually characterized severe winter symptoms. The likelihood that a serotonergic drug would work in this syndrome had been assessed to be significant, based on the previously demonstrated efficacy of the drug in another disorder ("carbohydrate-craving obesity) characterized by carbohydrate-craving, weight gain, and elevated Hamilton scores.

2.) Dr. Judith Wurtman, Dr. Amnon Brzezinski and their associates measured food and macronutrient intakes and Hamilton Depression Scale scores of women with or without clinical signs of premenstrual syndrome, both during the follicular and luteal phases, for six consecutive months. The patients were also followed by a gynecologist, who confirmed the diagnosis. They found that women with PMS - but not control subjects - showed abnormal Hamilton scores during the luteal, but not follicular phase. Moreover, they also exhibited a selective increase in dietary carbohydrate consumption with no change in protein intake, and this change in diet was sufficient to cause a real premenstrual weight gain not seen in the control subjects. The investigators suspected that the overconsumption of dietary carbohydrates was related to the previously demonstrated ability of this macronutrient to increase brain serotonin levels (i.e., by the insulin-mediated rise in brain levels of serotonin's precursor, tryptophan); an increase in serotonin was expected to be mildly antidepressant, and also to cause a selective decrease in elective carbohydrate intake. To test this hypothesis, they gave the two groups of women a test carbohydrate meal during the follicular

and luteal phases. They found that, in the women with PMS, the carbohydrate meal during the luteal phase was significantly antidepressant, lowering the Hamilton & Addendum scores to within normal range. In studies currently in press, they have shown that administration of serotonergic drug (d-fenfluramine) to such women can ameliorate both their appetitive and their affective symptoms.

3.) Dr. Richard Wurtman and Dr. John Growdon, in the study of potentiation of the efficacy of L-dopa in Parkinson's Disease, demonstrated that meals or snacks composed of carbohydrates (with or without fats) but lacking significant quantities of protein can exacerbate the clinical toxicity of L-dopa (e.g., the dyskinesias) in a Parkinsonian patient, and that the effect of the carbohydrate is related to its ability to cause an insulin-mediated decline in plasma levels of the large, neutral amino acids (like transport across the blood-brain barrier). This finding had been anticipated based on earlier studies in rats. It complements the observation made two decades ago by Cotzias that dietary proteins diminish the efficacy of L-dopa by raising plasma levels of the competing amino acids, and thereby diminishing the transport of L-dopa across the blood-brain barrier. The solution seems to be to give the patient nutritionally balanced meals or snacks, i.e., those containing a ratio of protein to carbohydrate which will cause plasma LNAA levels neither to rise nor fall. In an unpublished study, this nutritional strategy was found to work. A larger-scale study is now in progress.

4.) Dr. Harry Lynch and his associates conducted a study on "Psoralen Induced Melatonin Secretion". The object of his initial study was to attempt to confirm the reported effect of a therapeutic dose of 8-methoxypsoralen (8-MOP) on circulating levels of the pineal hormone, melatonin. They also monitored temporally-associated changes in mood and sleepiness (i.e., to see if the melatonin exerted its behavioral effects) and recorded the time course of 8-MOP absorption and metabolism. In a winter experiment, four volunteers were admitted to the CRC for 24 hours, and given a single dose of 8-methoxypsoralen (0.6 mg/kg) at 9:00 a.m. Plasma levels of the drug and of melatonin were measured at one- or two-hour intervals throughout the day. Only one of the four volunteers exhibited the expected response, i.e., a dramatic increase of plasma melatonin level following ingestion of 8-MOP at 9:00 a.m. While a transient peak in plasma 8-MOP was observed in each subject, three of them showed apparently normal melatonin profiles, low values during the day and marked nocturnal surge at night. One subject, who responded dramatically to the morning treatment, also displayed a significant phase delay in the onset of his nocturnal surge in melatonin secretion. Subsequent interrogation of the volunteers revealed that the single responder had an unusual life style; he was a student who routinely studied well into the night and slept in the morning. His central circadian time-keeping mechanism was phase delayed. At 9:00 a.m. the nocturnal increases in melatonin synthesis and pineal melatonin content apparently persisted. These observations suggested that the plasma melatonin response to 8-MOP might represent melatonin release, and that the time of 8-MOP administration is critical. Present studies involve giving the dose at 9:00 p.m. If a dose-characteristic response is seen with this schedule, and if the phenomenon can adequately be characterized, it may prove to be a useful tool in the study of pineal function and the role of melatonin in health and disease.

RICHARD J. WURTMAN

Division of Toxicology

The Division of Toxicology was established as an administrative unit within the Whitaker College of Health Sciences and Technology on July 1, 1988. The Division was established within the Whitaker College 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 now operational in the new 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. Appointment of one additional faculty member was authorized at the time of formation of the Division, and a search is in progress for candidates for that appointment. Professors James G. Fox and Hamish Munro are also affiliated with the Division. 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 genetic and genetically linked diseases in humans. The program requires thorough undergraduate backgrounds in chemical, biological or engineering sciences. Emphasis is placed on further classroom preparation in 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 previously 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 95 degrees in Toxicology have been awarded, 63 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 majors enrolled in the program was 30 to 35. The number of students declined to 26 because the administrative reorganization precluded admission of a new class of entering students in the spring of 1988. However, six new students entered the program in September, 1989, and an equal number for the 1990-91 academic year. Plans for the future are to admit eight new students in each successive year.

The degree program offers graduate level training leading to doctoral or master's degrees in Toxicology. In its teaching and research endeavors, the 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), with the original 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.

Dr. John M. Essigmann was promoted to the rank of Professor.

Dr. Helmut Zarbl is Robert A. Swanson Assistant Professor of Life Sciences.

Ms. Cynthia Leaf was the recipient of the Hugh Hampton Young Memorial Fellowship Award in recognition of her outstanding leadership, citizenship and academic qualities.

The M. M. Znaty Award for Graduate Research was presented to Mr. Brian Donahue in recognition of his doctoral thesis research with Professor John M. Essigmann.

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 Bernard S. Proctor Undergraduate Research Award went to Melissa Lucarelli, on the basis of her SB thesis research project.

GERALD N. WOGAN

CHAIR OF THE FACULTY

THE FACULTY POLICY COMMITTEE

This year the Faculty Policy Committee (FPC) was heavily involved in formulating and shaping issues for consideration at the Faculty Meetings. Some of these topics came to the Committee from faculty and presidential committees and departmental deliberations, but substantial efforts went to issues imposed from outside the normal channels of discussion and issue formulation.

Much of the year's activity concerned the quality of community life:

- The Committee revisited the Institute policy on pornography (which had been discussed at length during the previous two years) before the policy's final adoption by the Academic Council. Changes were suggested, and the need for clarifying the educational focus of such a policy was emphasized.
- Discussions of policies and practices regarding demonstrations began when demonstrations for divestment commenced in March. Ways to handle demonstrations while protecting the right of free speech formed the core of the issue. Several members of the FPC volunteered to attend demonstrations to serve as observers and to lend faculty presence. They also participated in a well-attended lunch meeting consisting of activists, faculty, administrators, and other interested parties. Throughout the spring, FPC members provided support for the Chair by being on call to attend demonstrations, offering advice through Committee discussions, and helping to ease tensions through constructive dialogue. The Committee served as a sounding board for the resolution proposed by several members of the faculty regarding demonstrations on campus and appropriate ways to handle them.
- The Committee was briefed on the military's policy on sexual orientation. The level of campus concern about this issue was raised by an MIT ROTC cadet's declaration of homosexuality and the Navy's immediate dismissal of the student and its demand that his scholarship money be repaid. The Committee reviewed the faculty resolution on sexual discrimination in ROTC and made several recommendations regarding its language and content.
- The Committee began discussions on harassment within MIT, learning that the number of incidents appears to be increasing. It offered input on the formation of a committee on sexual harassment, chaired by Professor S. Jay Keyser.

Another set of community life issues emerged from various Institute committees:

- The Equal Opportunity Committee (EOC) previewed its report to the Faculty about equal opportunity problems, solutions, and resources. The committee proposed that MIT should face squarely the issue of equal opportunity and that faculty should become more involved. The EOC advocated formation of a consortium of schools with the goal of increasing the number of underrepresented minorities choosing careers in science and engineering.

- The Freshman Housing Committee summarized its report on housing freshman and Residence Orientation Week. It recommended housing all freshmen on campus and making appropriate changes in R/O to accommodate this. The Committee also recommended making changes in residence programs, faculty involvement, and in student governance in the residential system to enhance quality of life and to increase support, particularly for freshmen; adding 350 beds to house freshmen; and planning a transition period to minimize adverse effects on the ILGs and to smooth the shift from freshman-year to sophomore-year pledging.
- The Committee on Family and Work presented preliminary findings and statistics prior to presentation to the Faculty. The FPC will likely return to the recommendations of the committee due to their far-reaching effects on the community.
- The Committee on Privacy raised concerns about the right to privacy versus the need to know and suggested that requests for information about students be handled by the Dean of the Graduate School, the Dean for Student Affairs, and the Dean for Undergraduate Education. FPC members suggested a comparable system for requests for information about other segments of the community.
- The Committee reviewed in detail several recommendations made by a small FPC subcommittee on the Committee on Discipline (COD). The Chair of the Committee on Discipline indicated that COD rules would be redrafted to reflect the FPC discussion.
- Finally, there was discussion of a new procedure for holding up a student's degree in the case of disciplinary action in the final days before graduation from MIT. The Committee agreed that a system should be in place to assure proper handling of disciplinary situations that might arise.

A number of issues regarding academic policy and Institute structure came to the FPC for consideration:

- Professor Margaret MacVicar, Dean for Undergraduate Education, reported on activities of the Committee on the Undergraduate Program. These included proposed calendar revisions, discussions of truth in advertising regarding work load for courses, and educational commons activities.
- The Committee on Undergraduate Admissions and Financial Aid followed up on its report of the previous year, citing more faculty input in admissions and changes in admissions criteria.
- Changes to the appointment structure for athletics faculty were endorsed with emphasis placed on preserving the link between members of the athletics department and the rest of MIT.
- A preliminary report was made by the chair of the IAP Policy Committee that indicated moderate success at improving IAP participation and offerings. The report recommended continuing IAP, but shifting responsibility for content to departments.
- Proposals to extend the exam/reading periods, especially in the spring semester, were presented to the FPC. Student members of the Committee made several recommendations, some of which were incorporated into the final proposal voted by the Faculty.

Plans for an intensive review of the academic calendar were discussed, and the Chair decided to form a subcommittee next year to work on this topic.

- The Committee reviewed a proposal submitted by the Department of Civil Engineering for a new S.B. in Environmental Engineering and endorsed it.

Finally, the Committee was able to devote time to some broad longer-term issues of concern to the Faculty and the Institute:

- Staff from the *Faculty Newsletter* presented the *Newsletter's* funding needs, structure, and goals.
- The Ad Hoc Committee on the MIT Lincoln Laboratory outlined its report prior to presentation to the Faculty. The report considered divestment of Lincoln Lab from MIT, establishment of a visiting or advisory committee, and cultural differences between MIT and Lincoln Lab.
- Members of the Faculty Advisory Committee to the Corporation on the Presidential Search described their role in the presidential search process and sought advice from FPC members.
- Continuing what has become a tradition, the Committee invited President Paul E. Gray to join it for a meeting. He took this time to reflect on several topics: his successor, the transition to a new administration, tasks facing the president of MIT, and issues relating to education in the United States.
- Professor Kenneth Smith presented the Institute's new Academic Fraud and Misconduct Policy, emphasizing changes which resulted from the new Public Health Service requirements. Institutions receiving funding from the PHS must be in compliance with these regulations. The new PHS regulations do not differ greatly from previous MIT procedures.
- In response to a suggestion that the deans from the five Schools be invited to the FPC to provide information on School directions and initiatives, Dean Gerald Wilson (School of Engineering) reviewed past, present, and future initiatives for the School. His remarks focused on academic computation, the review of the School's undergraduate education program, the possibility of a five-year degree program, the intertwining of technology and policy, and funding for research and educational activities.
- Toward the end of the year, it became evident that the role of the FPC merits evaluation and clarification, a topic that will be on next year's agenda.

The Chair thanked all who had served on the Committee this busy year and bid farewell to departing members Professors Penny Chisholm, Robert Fogelson, and Harvey Sapolsky, and Mr. Michael Grossberg and Ms. Elizabeth Williams (graduate and undergraduate members, respectively).

THE COMMITTEE ON THE UNDERGRADUATE PROGRAM

The Committee on the Undergraduate Program (CUP) fulfilled this year's goal to monitor and prod into action various initiatives and experiments. A subcommittee was formed to construct language for *Rules and Regulations of the Faculty* and devise implementation plans regarding pass/no record as voted by the Faculty in May 1989. A report on the status of design plans for a biology requirement was heard, a topic that CUP will take up again next year. The Committee initiated discussions on the implications of Pass = C for advising, subject planning, and R/O.

The annual Winter Work Session entitled *Who are We?* focused on the diversity of the MIT community. CUP members and several guests heard presentations on the MIT community, the student body (admissions and financial aid aspects), and activities both in and out of the classroom. The day was highlighted by lunch discussions in small groups with students representing a broad spectrum of backgrounds and interests. The concluding session summarized the lunch discussions and outlined ways to continue exploration of the topic of diversity.

CUP endorsed a proposal submitted by the School of Humanities and Social Science to eliminate level IV language subjects from the HASS-D system and to establish a Language One Option that allows students to substitute one language subject at the level of III or IV for one HASS-D subject.

As has been its custom, CUP heard reports from several committees and individuals throughout the year. These include the following:

- Dean McBay briefed CUP members on programmatic changes in the Interphase Program and the establishment of the Excel Program.
- The Context Review Group, chaired by Professor Francis Low, presented its conclusions about the Context notion. These included unanimous and enthusiastic support for the Context notion as an important component of an MIT education for undergraduates, graduate students, and teachers. The group urged the continuation of Context subjects and programs and offered recommendations for doing so.
- In compliance with the motion voted by the Faculty in May 1987, the School of Humanities and Social Science gave its annual HASS-D implementation status report. New HASS-D subjects are being offered, old courses have been restructured or removed from the list, and the balance of offerings across the five categories is improving. Also noted was the progress made in offering minor programs in HASS.
- CUP discussed the recommendations of the Freshman Housing Committee with its chair, Professor Molly Potter. These included preassigning freshmen to housing on campus before orientation, adding to the number of beds on campus, and improving programs related to residential life.
- The Committee was updated on Project Athena and work by the Committee on Academic Computation for the 1990s and Beyond.
- The Committee on the Science Requirements informed CUP of its intent to assess the pilot programs and develop recommendations to the Faculty for inclusion of biology in the Science Component of the General Institute Requirements, to review the objectives of the Science Distribution and examine the list of individual subjects to insure that the

Science Distribution fulfills its purpose, and to review on an ongoing basis the content and appropriateness of the Science Component of the General Institute Requirements.

- Progress on establishing an Institute-wide planning system for educational commons activities was reviewed twice.
- A proposal to extend the fall and spring semester final exam periods to five days with related calendar changes was considered. Recommendations were made before the proposal was presented to the Faculty for a vote.
- The IAP Policy Committee reported on its deliberations, finding that IAP is a viable enterprise that should continue, that students have responded positively to credit-bearing offerings, and that faculty participation is not at a sufficient level. The committee made several recommendations.
- Informational discussions took place concerning ROTC on campus and the military's policy on sexual orientation. Commanders of the MIT ROTC units joined CUP for a meeting.
- Professor David Wormley presented progress reports on a proposal submitted to the National Science Foundation for a program to renew undergraduate engineering education and to attract more students into the field of engineering, particularly women and minority students.

CUP bid farewell to departing members Professors Philip Khoury, Kenneth Manning, and David Gordon Wilson, Dean Shirley McBay, and Mses. Anne Louit and Deborah Nungester (undergraduate student members).

OTHER FACULTY COMMITTEE REPORTS

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year:

The Committee on Academic Performance (CAP) held 15 regular meetings during the academic year to consider matters related to the academic performance of undergraduate students. Approximately 450 individual petitions were considered pertaining to changes in registration after the published add- and drop-dates, grade changes between pass/fail and letter grades, and the completion of incompletes, among other issues. At the end of both the fall and spring terms, the Committee met with members of the Undergraduate Academic Support Office and Departmental academic officers to review the academic records of all undergraduates in order to detect problems and try to help students in academic difficulty. The Committee recommended to the Faculty all candidates for the Bachelor's degree.

The CAP also worked with the Committee on Curricula and the Committee on the Undergraduate Program on issues concerning graduation under the new General Institute Requirements and the implementation of the freshman Pass/No Record system voted by the Faculty. Finally, the CAP held two meetings to coalesce ongoing discussions of evening exams into a set of guidelines for their conduct. These evening exam guidelines were submitted to the Chair of the Faculty.

The Committee on Corporate Relations' agenda was dominated by the data gathering activities and hearings of the US House of Representatives Subcommittee on Human Resources and International Relations concerning the relationships between universities and their faculty and foreign-owned corporations. The Committee consulted with the President's Office and the Office of Corporate Relations about the evolving study and its implications for the Institute.

The Committee on Curricula's (COC) major charge is to consider petitions from students for substitutions in Institute degree requirements and to approve changes in undergraduate subjects and curricula, as proposed by the departments concerned. This year, in addition to these duties, the Committee addressed three further issues:

- 1) The Committee foresaw that the change in the general requirement for an MIT baccalaureate degree from 360 credits to at least 180 credits beyond the 17-subject General Institute Requirements (as mandated by a faculty vote in Spring 1989) might lead to confusion and a flurry of last-minute petitions from the seniors of the 1990 class — the first class for whom this change had full effect. A meeting of the Registrar and COC chair with the collected undergraduate academic officers of the departments brought out a general perception that there might be serious problems with scheduling the final year of many seniors who, despite public notice and written warnings to students and advisors, had not taken account of the changed requirements. The clear position of the COC was that first and foremost each situation would be judged individually on its educational merits, and that to a reasonable extent, for the 1989-90 year, variances aimed at minimizing enforced symbolic behavior (e.g. staying an extra semester to complete one subject needed only for units) would be allowed. Very few petitions came in, a tribute to the resourcefulness of all concerned.
- 2) The COC is often asked to approve credit for subjects beyond the current established credit limits for work done during IAP. After some philosophical examination of the topic and consultation with the chair of the IAP Policy Committee, the Committee concluded that since IAP is approximately one fourth of the length of a term and since 60 credits is a reasonable yield for a full term, then 15 credits might be an educationally reasonable absolute upper limit for credit earned during IAP, considering the level of effort plausible for a given day in a student's career. This will be discussed further next year.
- 3) The Committee debated the meaning of the unit of credit, conventionally one hour of effort per week for a 14-week semester, as the COC is often asked to approve unit changes and unit designations for new courses. The Committee reviewed evidence on "real effort" as opposed to credit awarded, as gleaned from a study of the undergraduate course guide. The Committee is contemplating a pilot study for 1990-91, aimed at testing hypotheses about the relationship between course load, traditionally time-consuming courses, and attention to other courses taken concurrently. The aim is to help faculty refine their expectations, in particular in understanding the trade-offs in the pace and pressure issue.

Doubtless these and related matters will continue to occupy the Committee's attention in the coming year.

The Committee on Discipline (COD) adjudicated a number of grievances against students brought to the Committee by members of the MIT community. Among these were cases of academic dishonesty including plagiarism, cheating on quizzes, and collaboration on computer code; harassment in the form of threatening messages sent over the Athena system; falsifying and selling phony Massachusetts drivers licenses to underage students for the purpose of obtaining alcohol; and confrontation and violence at a meeting of the MIT Corporation associated with protest of MIT's investment policies. The sanctions included formal and informal academic probation, letters of reprimand, and participation in alcohol rehabilitation programs. The Chair participated several times with the Faculty Policy Committee in discussions of revisions to the MIT grievance procedure and in discussions of MIT's pornography policy. The Chair also met regularly with staff members involved in the grievance procedures across the Institute in order to coordinate activities and share issues and ideas.

The Committee on Faculty-Administration (CFA) met twice during the year. The first meeting was devoted to a discussion with Professor Peter Elias, Chair of the Committee on Family and Work, of his committee's report prior to its presentation to the MIT community. The second meeting was devoted to a discussion with Professor Daniel Holland, Assistant to the Provost, of a plan being proposed to facilitate faculty retirement in the face of federal legislation that would make it illegal for universities to impose on faculty mandatory retirements based on age. No action was called for on the part of the Committee in either case.

Among the items dealt with by the Committee on the Library System were selection of a vendor for the new CD-ROM Catalogue, allocation of additional collections money, selection of the Associate Director for Public Services, and review of the annual report and planning process.

The Committee on Nominations filled approximately 40 positions on the 14 faculty committees and also nominated the Chair-elect of the Faculty. Considerable emphasis was placed on involving more faculty in the governance system. Emphasis was also placed on staffing the committees with faculty who have the leadership potential to chair these committees in the future. The Committee was also dedicated to obtaining balanced representation from the entire spectrum of MIT Schools and departments.

The Committee on Outside Professional Activities was faced with two significant issues this year: the interpretation of the "fifth day policy" and the emergence of the issue of conflict of interest and scientific misconduct. The first is a perennial issue of what MIT means when it says that a full-time faculty member should not devote more than one day a week to outside professional activity. Does this mean one day out of the five-day work week or one day out of the total seven-day week? In the second interpretation there is a question as to what one can or cannot do in terms of consult/professional activity with the remaining two days in the week. Because there is no case law on the issue, but only good practice on the part of department heads and deans, there seems to be a variety of interpretations of the meaning of the fifth day. The majority interpretation is to view it as one day in a seven-day week for outside activity for a full-time faculty member, but there is pressure from a variety of fronts for a more liberal interpretation. Administrators have to fight hard to hold the line. After consultation with Dean DeMonchoux, the decision was made to turn the issue over to the deans and to the Academic Council because the policy implications warrant their intervention.

Regarding the second conflict of interest issue, the Committee awaits the formation of an ad hoc committee with representation from the Committee on Outside Professional Activities.

The Committee on Student Affairs (CSA) held meetings of the full committee and/or its subcommittees at least once a month during the academic year. The Committee continued to serve as a forum for airing and discussing concerns about student affairs that can benefit from interaction among students, faculty, and representatives of the Office of the Dean for Student Affairs.

The bulk of this year's activities focused on the work of the three subcommittees organized last year: the chaplaincy, mutual respect and diversity, and international students. The Committee's interest in these three topics arose from different circumstances and events. However, the Committee saw some evidence in all three topics of a growing uneasiness about the quality of personal interactions within the MIT community and the need for MIT to adopt an active rather than re-active role in promoting mutual respect and building upon our (increasing) diversity.

The chaplaincy subcommittee, chaired by Professor James Melcher, was the first to complete its work and prepare a report for the CSA. This report proposes the formation of a Presidential Committee on Campus Religious Affairs. In making this proposal, the CSA is not advocating that MIT promote, organize, or even manage religious activities. The CSA is comfortable with MIT's institutional relationship to campus religious activities, which is to treat them as autonomous units. However, the CSA shares a concern that implementation of this policy has swung so far that routine communication and interaction does not often occur. Moreover, the diversity of religious experiences and their links to MIT are growing in ways that are likely to increase the need for periodic discussion of the chaplaincy and the nature and scope of campus religious affairs by a broadly based group of interested members of the MIT community who can offer constructive advice to the administration.

The chaplaincy report was discussed and revised by the full CSA this spring and a final draft was sent to the Faculty Policy committee (who had earlier forwarded the issue to the CSA) and to President Gray (since the Committee proposes a Presidential Committee).

The work of the other two subcommittees will continue into next year.

The Committee on Undergraduate Admissions and Financial Aid (CUAFA), as one of its major tasks of the year, undertook an effort to increase the level of faculty participation in the admissions process. Early in the fall semester, each department head was asked to designate a faculty member to serve as liaison to CUAFA and the Admissions Office and was also urged to encourage departmental faculty to read admissions folders. As a result, faculty participation reached an all-time high, with 38 faculty members reading over 1,000 folders, more than double the number read in the previous year.

To further encourage faculty involvement, CUAFA, in collaboration with the Office of Admissions, arranged a pre-admission session in which faculty readers and departmental liaison met with admissions staff to discuss and compare votes on a sample of 30 applicants. Subsequent to completion of the admissions cycle, the same group met again to review the admissions decisions actually made. It was universally agreed that these meetings provided an

extremely useful and instructive interchange between faculty and admissions staff, and should be repeated next year.

In response to recommendations by CUAFA and the Student Financial Aid Office, the Academic Council this year approved a policy change that will allow all students on aid who receive eligible outside scholarships to reduce their self-help expectation by 40 percent of the award. This new policy replaces the existing Pilot Outside Scholarship Program, which is less generous to students and applies only beyond the freshman year.

This year the Committee on the Writing Requirement has been actively engaged in overseeing the administration of Phase I, completing the transition of most of the responsibility for Phase II to departments, and establishing policy and procedures to enforce the Faculty's rule that students must complete Phase II by Registration Day of the term in which they are to graduate. In addition, the Committee, acting under its charge from the Faculty, has begun a review of the departmental Phase II plans. The Committee approved Phase I credit for the Project Interphase writing subject and Phase II credit for a Course 15 writing subject. The Committee also acted on 87 petitions from students.

The Committee is pleased to report that, although three students were prevented from graduating on the June S.B. degree list solely because of the Writing Requirement, students are fulfilling the Requirement earlier and faculty are reporting a definite improvement in the quality of undergraduate writing.

The Harold E. Edgerton Faculty Achievement Award Selection Committee selected Associate Professor Stephen L. Buchwald in the Chemistry Department. In giving this award, the Committee stated that Stephen Buchwald, a leader in innovative and creative organometallic chemistry "has synthesized extraordinarily interesting molecules such as benzyne and cyclopentyne complexes which he fully characterized" and that "with these new complexes he has developed efficient syntheses of pharmaceutically important compounds." Buchwald "has succeeded in motivating and exciting his students about their research problems ... his love of science is contagious." The Committee concluded that Stephen Buchwald "is a complete, academic scholar — interested and effective in all components of our educational enterprise."

The James R. Killian, Jr. Faculty Achievement Award Selection Committee issued its call for nominations in December 1989. Eleven nominations were received. Additional information was requested for a short list of three, and Professor George H. Buchi was selected as the 1990-91 recipient. The Committee cited Professor Buchi's contributions in "photochemistry, natural products, and molecular toxicology which comprise cornerstones of these diverse areas of organic chemistry." It further stated that "His creativity and style in organic chemistry have inspired fundamental work by others, and his laboratory has attracted many outstanding students and postdoctoral associates... His pioneering work on light-catalyzed organic reactions in the early 1950s opened up an area of investigation that has yielded insight into the relationships between electronic structure of molecules and chemical reactivity. Modern organic photochemistry can be traced to Buchi's pathmaking work at MIT..."

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: Preetinder S. Virk (Academic Performance), Nicholas P. Negroponte (Corporate Relations), William H. Orme-Johnson (Curricula), Sheila E. Widnall (Discipline), Jack P. Ruina (Faculty-Administration), Paul Osterman (Library System), Robert V. Whitman and J. Kim Vandiver (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), Kip V. Hodges and Suzanne Flynn (Writing Requirement), Isabelle de Courtivron (Edgerton Award Selection), and Donald R. F. Harleman (Killian Award).

Henry D. Jacoby
Laura B. Mersky

SCHOOL OF ARCHITECTURE AND PLANNING

Planning for change characterized the activities of the School's three academic units -- the Department of Architecture, the Department of Urban Studies and Planning, and the Media Arts and Sciences Section.

Academic Program

Over the year Department of Architecture faculty committees addressed issues of group governance, curriculum change and realignment and strengthening of disciplinary clusters. Included in these deliberations were the decision for a major relocation of design studios and steps toward the development of a new program, MArch II, to offer advanced design work to students with a five-year professional degree in architecture.

By approving a new curriculum that puts the preprofessional program in architectural design on an equal basis with three new concentrations (building technology, history of art and architecture, and visual arts), the department enhanced the School's contribution to the Institute's undergraduate education. In the fall, the department's visual studies program started its teaching program, which includes Visual Fundamentals, a new undergraduate foundation subject. An expanded faculty in the history, theory and criticism program contributed several new undergraduate subjects, an undergraduate HAAS minor, and a concentration within the department's undergraduate degree.

Much of the planning effort in the Media Arts and Sciences section was focused on the forthcoming academic review by the School in the spring of 1992. Within the section there was a noticeable trend of emphasis on the Doctoral program as Master's students elect to continue their education here. Although the section has no official undergraduate academic program, its offering of Holographic Imaging was granted standing as an Institute lab requirement. Further, 106 UROP students were active in the Media Laboratory.

Mirroring a rapidly changing world, the Department of Urban Studies and Planning embarked on a systematic long-range planning effort a year and a half ago. Recently, and at the end of his term as department head, Professor Tunney Lee accepted a two-year assignment with the Chinese University of Hong Kong to set up a new architecture school. The department has established a planning process that will support the new department head, Professor Donald Schon, and the assistant head, Professor Phil Clay, as they take up the responsibilities of leading the department and the challenge of relating day-to-day decisions with a broad look at the mission of the department.

During its sixth year of operation, the academic program supported by the Center for Real Estate Development expanded its relationships with similar programs in other countries. Professor James McKellar, Director of the Center for five years is returning to full-time teaching and research. Professor Lawrence Bacow will be the new director. Mary Lou Boutwell, MSRED '87, will take up a new position as Associate Director.

Research

Research development out of the Dean's Office focused on housing research. A gift from John Bemis of Acorn Products supported a new Visions in Housing research effort to supplement the School's efforts in past years supported substantially by the existing Bemis Fund.

A new School Computation Committee worked on recommendations that will be issued this fall. The departments' research efforts included the establishment of two consortia of industrial sponsors to support housing construction research.

The Media Lab's research volume reached \$7.5 million, continuing a pattern of growth but at a slower rate that reflects the Media Lab's attainment of planned size and capacity. Under the direction of Nicholas Negroponte, the Lab created and implemented a major new long range international research program called Television of Tomorrow (TVOT).

Financial Support

The Dean's Office continued its program of alumni breakfasts with events in Boston, Los Angeles and New York. Fundraising efforts yielded gifts for the renovation of Rotch Library, and for professorships and fellowships. The Community Fellows Program received funding from the Ford Foundation to contribute to the support of mid-career professionals from around the country to work on issues of youth development. Support was also secured for the new Berenice Abbott Photo Lab in the visual arts program.

The Media Laboratory continued its expansion of sponsorship, including a career development chair funded by the Sony Corporation and a major new fund from Nintendo Company, Ltd. to support research into how children learn while they play. Research groups in the Lab also benefitted from several grants of equipment.

Facilities

The new addition to Rotch Library neared completion, nearly tripling the amount of space at the Rotch location. Other space changes included the decisions to relocate design studios to Building N52 and to improve the first floor of N51 for the visual arts program. Building Technology laboratories, including the Sylvania Lighting Laboratory, will be relocated to the vacated design studio space on the fourth floor of Building 7.

The library building project offered opportunities for other School improvements that would reconfigure our facilities to align with the intellectual and administrative distribution of our activities. However, after a sustained planning effort within the School, the Institute's Committee for Review of Space Planning vetoed such additional physical improvements for the near term in the light of severe financial pressures.

Community Composition

The School's total enrollment decreased from 602 to 578 students. Of this total 37 percent were women and 10 percent were under-represented minorities (23 percent in the Department of Urban Studies and Planning). The numbers of women and minority faculty members were at a level comparable to last year.

The Minority Developers Executive Program in the Center for Real Estate Development expanded to 30 participants for its second session last fall. The CRED faculty taught in the program on a pro bono basis.

A School-wide committee on affirmative action initiatives reviewed appointments, promotions, and searches with the goal of consolidating the School's gains and continuing the efforts to improve its affirmative action record. Among the past year's accomplishments were two target-of-opportunity appointments and a program plan for active recruitment of under-represented minorities. This program is intended to bring new faculty into the School on a strategic schedule of visiting appointments.

John de Monchaux
Dean

FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1989-1990

	1988-1989				1989-1990			
	Total	Full Time Equivalent	Women	Minority	Total	Full Time Equivalent	Women	Minority
<u>Department of Architecture</u>								
Faculty	24	23	2	0	25	24	3	0
Other Academic Staff	37	23.75	6	0	34	18.25	3	0
Research Staff	2	1.5	0	0	2	1.5	0	0
Without Pay	4	2.5	2	0	1	1	0	0
<u>Department of Urban Studies and Planning</u>								
Faculty	25	23	5	4	24	24	5	4
Other Academic Staff	22	14.33	7	4	17	10.5	8	3
Research Staff	2	1.5	0	-	2	1.75	-	-
Without Pay	23	13.2	9	12	18	7	8	9
<u>Media Arts and Sciences Section</u>								
Faculty	12	12	3	0	13	13	3	0
Other Academic Staff	5	4.7	2	0	5	4.2	1	0
Research Staff	0	0	0	0	1	1	0	0
Without Pay	5	2.25	1	0	3	2.08	0	0
<u>Laboratory of Architecture and Planning</u>								
Faculty	-	-						
Other Academic Staff	1	.25						
Research Staff	2	1						
Without Pay	8	4						
<u>Media Laboratory</u>								
Research Staff	23	21.27	5	1	27	24.9	2	1
Without Pay	NA	NA	NA	NA	17	17	2	0
<u>School Totals</u>								
Faculty	61	58	10	4	62	61	11	4
Other Academic Staff	65	43.03	15	4	56	32.95	12	3
Research Staff	6	25.27	0	1	5	29.15	0	0
Without Pay	40	21.95	12	12	39	27.08	10	9

STUDENT ENROLLMENT AND COMPOSITION 1989-1990

	Total	Women	Minority	International
Department of Architecture				
Undergraduate	119	58	6	9
M.Arch.	99	35	5	11
S.M.Arch.S.	41	12	2	32
S.M.Vis.S.	5	3	0	2
Ph.D. (resident)	15	6	0	7
S.M. Real Estate Devel.	17	4	0	3
S.M. Building Technology	2	1	0	0
Total Graduate Resident	179	61	7	55
Ph.D. (nonresident)	15	3	0	7
Special Students (nondegree)				
ARCHITECTURE TOTALS	313	122	13	71
Department of Urban Studies and Planning				
Undergraduate	5	2	3	-
M.C.P.	94	42	32	20
S.M.Real Estate Devel.	15	1	2	
Joint M.C.P./M.Arch.				
Ph.D. (resident)	30	11	1	11
Total Graduate Resident	139	54	35	31
Ph.D. (nonresident)	33	18	5	15
Special Students (nondegree)				
SPURS	13	2		13
CFP	-	-	-	-
DUSP TOTAL	172	72	40	46
Media Arts and Sciences Section				
S.M. (unspecified)	44	8	1	10
Ph.D.	31	7	3	1
Special Students	-	-	-	-
MAS TOTALS	75	15	4	11
School Totals				
Undergraduates	124	60	9	9
Graduate	441	151	51	119
Special Students	13	2	0	0
TOTAL ENROLLMENT	578	213	60	128

Department of Architecture

Significant changes have been effected in most parts of the department this year, and in the next year searches to be opened up should take better advantage of our internal diversities and of the complementarities that exist between Architecture, Urban Studies and Planning and other departments and centers at MIT. The Matrix Committee went through a planning exercise in the spring term, sharing the results with department faculty, students and, in May, with a subcommittee of our Corporation Visiting committee in a special session. The objectives were to lay the groundwork for the next version of a department five year plan which will enjoy commitment not only from the Matrix leadership group but from the entire department; to scrutinize specific problem areas--i.e., the teaching of advanced design, the structure and content of Architecture Studies, and leadership for the Architectural Design discipline group; and to provide continuity for a transition of leadership expected in the coming year.

Some disciplinary clusters have been strengthened--History, Theory and Criticism (HTC) and Building Technology (BT) in particular--and Visual Studies has made a strong start this year. Architectural Design spent a large part of the year wrestling with the issues of group governance. With that issue somewhat better understood, the design faculty worked together to address issues of the substance and structure of the introductory design curriculum. In Architecture Studies resignations this year and last of a number of key faculty inevitably present both opportunities and questions. The coming year should see substantial redefinition of this discipline area, which will importantly affect the SMArchS program that derives content from its teaching.

A major decision was made this year to reconfigure department space, with the intention ultimately to locate all architectural design studio teaching in Building N52 and SMArchS activities in the main complex. This year the new visual studies program was begun in studio and shop spaces on the first floor of N51, and upper level architectural design studios occupied adjacent spaces in building N52. Over the IAP period, through a series of well-planned entrepreneurial moves, a student team headed by MArch students Daniel Johnson ('91) and Albert Vallecillo ('91) succeeded in transforming the space into attractive and useful studios and an exhibition area. Further renovation of the N51-52 complex for the visual studies program will be undertaken by the Institute and readied for the fall term, 1990. Professor John Myer has taken responsibility for short-term space planning and logistics for the department; Professor Jan Wampler and a faculty committee have addressed issues of long-term space needs.

PROGRAMS

The department enrolled a total of 282 regular students in its five programs in fall AY 1989-90. The number of undergraduates majoring in Course IV appears to have leveled off this year at 119 students, peaking last year after a steady four year rise. Graduate students numbered 163, with all programs--MArch (99), SMArchS (44), SMVisS (5) and PhD (15) remaining approximately the same size as last year.

Professor Leon Groisser, chairman of the undergraduate program, has written a curriculum proposal that has been approved by the faculty. The new requirements will be in effect for majors entering the department in fall, 1990. The new curriculum will put the four discipline concentrations (architectural design, building technology, history of art and architecture, and visual arts) on an equal basis. Until now the undergraduate program has been seen as essentially a pre-professional one, with almost all Course IV majors concentrating in the area of architectural design.

The new undergraduate curriculum will require that students take subjects in each of the four areas before deciding on a concentration. This specific, broad preparation will provide a common set of experiences for all undergraduates on which to build further educational experience and will encourage students to think about options in the architecture in addition to design. Each discipline group has responded to the curriculum proposal with new and revised subjects: The design faculty has, as a first step, ordered its introductory design curriculum and requirements to fit the program; building technology has devised new subjects for an undergraduate concentration, partly in hopes of preparing undergraduates specifically for its graduate program; the appointment of a second history of art professor, and the resultant expansion of offerings in art history and HTC, make an undergraduate major in that area feasible and attractive; and finally, the development of a new visual studies program, as specifically directed by the Institute, will ultimately make possible a sequence of quality intermediate and advanced visual arts subjects necessary for concentration in that area.

Curriculum changes drawn up by a committee chaired by Professor Thomas Chastain were implemented this year in the professional Master of Architecture program. Objectives of the proposal were to guarantee better coverage of the wide range of material students entering the architectural professional should master and to make more effective use of the range of disciplines and skills available in the department and the Institute at large. Modifications to the thesis process include extending the thesis work over the two last semesters, earlier association of student with thesis advisor, and more exposure of the thesis work to the department community.

Research and Advanced Study was comprised mainly of the post-professional degree (SMArchS) program whose candidates are based principally in Architecture Studies and the PhD, with candidates mainly in History, Theory and Criticism of Art and Architecture (HTC). A small advanced studies program in Visual Arts (SM Visual Studies), that remained under the direction of Professor Otto Piene, will be restudied after the undergraduate program in visual arts is underway and after new faculty have been recruited. In addition, the new joint degree program for an MS in Building Technology, which is anchored in this department, accepted four students this year and will be up to full complement in fall '90.

Professors Stanford Anderson and Leon Glicksman, with counsel from other colleagues in advanced studies, reported to the Matrix Committee this year on the general issue of department PhD programs. It was their conclusion that doctoral study and research should derive from intellectual agenda rather than simply evolve from existing degree programs. As new faculty are recruited and as the discipline groups clarify their interests and resources, advanced study at the appropriate levels can be defined. Doctoral studies will therefore continue to be based primarily in HTC and BT in the near term.

DISCIPLINE GROUPS

This year for the first time the Architectural Design faculty established itself as an autonomous discipline group within the department along the lines of the HTC or Building Technology groups. This new organizational structure assisted the design faculty in generating action on curriculum questions, space planning, and teaching responsibilities and the result has been an invigorated debate on the nature of design education and the contemporary architectural profession. The expression of this debate can be found in the diversity of studio offerings and the expanding range of interests represented in the faculty. The coalescing around an organizational structure is expected to be augmented when the faculty is situated together physically in new offices in N52. This spirit of openness and collective action is key in addressing the transition the faculty group is expecting in the coming few years.

Several important curriculum initiatives have been undertaken in the past year. One of the most important was a proposal and some development of a new program for students with a five year professional degree in architecture. Slated for implementation in the fall of 1991, the new

program will focus on advanced design work. Though applications for graduate MArch admission continue to be high, real concern surfaced this year about the number of MIT undergraduates who are electing other graduate schools to for professional degree study. This issue has had decided impact on design curriculum discussions, increasing the pressure to develop and offer advanced design teaching soon.

The Visual Arts program, under the leadership of Professor Edward Levine, started teaching subjects this year for both MIT undergraduates and graduate students. The program is based on the idea that discovery is central to the artistic process and this process of inquiry has broad applications to the attitudes and thinking central to other disciplines at MIT. The Visual Arts program is an effort to explore where artistic thinking and thinking in other disciplines overlap. Teaching stresses the idea that media are ways of exploring our inner and outer worlds--the connections between perception and conception.

Subjects were offered in Visual Fundamentals, Photography, Sculpture and special topics such as Dimensions of the Body. Two new faculty members taught this year in the program. Ritsuko Taho taught Fundamentals and Sculpture. Rick Bolton taught Fundamentals and Photography. The program started its computer lab and received numerous donations including two color printers from Textronix. Lengthy planning sessions with School and Institute groups yielded a plan and promise of renovated spaces in building N51 and 52 for Visual Arts studios and photography facilities. A search conducted this year ended in a recommendation that Ritsuko Taho be hired in a tenure track position beginning in Fall 1990. Visual Arts Program faculty have also started preliminary discussions with Mushashino Art University in Tokyo, around the establishment of a faculty and student exchange program.

Research and teaching in Building Technology, both for undergraduates and graduates, have been expanded in the past two years, under Professor Glicksman's leadership, and with the energy of the new junior faculty members, Professors James Axley and Les Norford. The group completed a search for another new faculty member to contribute to the creative technical design and innovative application of new technologies to buildings. Leonard Morse-Fortier, whose background is in structural engineering, design, has come from the University of Notre Dame to begin an appointment as assistant professor in July 1990. One further faculty search in the area of environmental controls will be opened in the coming academic year. New and improved building technology laboratories, including the Sylvania Lighting Lab, have been established on the fourth floor of building 7 in space vacated by architecture studios. BT research project subjects include building materials and systems concepts, indoor air quality, and energy efficient operation of building advanced thermal insulations.

For the first time in many years, the History, Theory and Criticism (HTC) of Architecture and Art program was almost fully staffed and the faculty all in residence. The one exception was the professor for history of architecture in non-western cultures, partially funded by the endowment of the Aga Khan. The visitor in that line was Mohammad Al-Asad, who also completed his doctorate at Harvard this year.

The HTC section, with the special effort of Professors Leila Kinney, David Friedman, and Benjamin Buchloh, has made several contributions to undergraduate education: several new subjects, an undergraduate HASS minor in the history of art and architecture, as well as an HTC concentration within the department undergraduate BS degree. Both Professors Francesco Passanti and Anderson have developed new subjects integral to the professional MArch program and participated in other aspects of that program.

The increased enrollments generated by new faculty and subjects intensify the problems created by the deplorable conditions of lecture and seminar spaces serving the section. The Institute has offered some relief in the form of three classrooms for HTC use, but the main lecture rooms require renovation.

The application pool for graduate studies in the HTC section (both SMArchS and PhD) remained strong in numbers and quality. The perceived quality of the incoming students in fall 1990 is very high. Though high MIT tuition costs and competitively low scholarship funds continue to put us at a disadvantage in seeking the best graduate students, this year we appear to have succeeded despite disadvantages.

The Architecture Studies group undertook a study of its activities in response to a number of pressing concerns, including the departure of a number of key faculty. Professor Ronald Lewcock, director of the Design for Islamic Societies section and Nabeel Hamdi, co-leader of the Housing and Design section, will be leaving the faculty during the 1990-91 academic year, and Lawrence Vale has been appointed as Assistant Professor in the Department of Urban Studies and Planning. The study made by a committee of Professors Julian Beinart and Passanti and Mr. Vale, proposed an intellectual focus around a study core which would diminish the current compartmentalization of sub-disciplines, but would retain the possibility of specialization in, for example, Design for Islamic Societies. New faculty would be sought according to this model and the group would seek to be housed together in the building 7 area as soon as possible. The new faculty positions will be filled so as to complement the strengths of existing faculty. They would focus on the production of architecture under different conditions of society and culture and on problems of change and continuity in the built environment.

There was also the ten year review of the Aga Khan Program at both Harvard and MIT, one component of which is the Design for Islamic Societies section in this department. Recommendations for the section included giving a stronger role to the academic departments for the management and direction of the degree program and a much higher degree of integration within its academic setting and the institution at large. These findings and recommendations are entirely consistent with and supportive of the conclusions of the previously mentioned study committee.

There has also been consistent demand by SMArchS students based in Architecture Studies for advanced design teaching. The proposed advanced design stream in the MArch program can enlarge the environment of post-professional studies in the department as well. There is therefore a need to engage the design faculty as they attempt to determine the character of advanced, or Level III, design teaching, perhaps even to integrate teaching at that level. Development of the MArch II program must include that issue. It will be essential to engage the other areas of the department as well as they determine what is appropriate for advanced study.

FACULTY

New faculty in 1989-90: Professor Levine came this year as a tenured professor to build and direct a new visual arts program for MIT undergraduates. Professor Levine was formerly Dean of the School of Art at East Carolina University. Other new visual arts faculty members were Ritsuko Taho, a sculptor who has taught in Japan, at Yale and Harvard, and Rick Bolton, a photographer, writer, editor and teacher who has taught at a number of universities in the past, including MIT in the Visible Language Workshop. In Architectural Design, Wellington (Duke) Reiter joined the design faculty for the year and Cameron Roberts for the fall term. Each taught Level I studio, and Mr. Reiter developed and taught a very successful version of 4.04 (Observing Architecture) as well.

Visitors: Paolo Ceccarelli, Director of the University Institute of Architecture of Venice, taught a seminar on City Form in the fall term, and generally substituted for Professor Beinart in the Architecture Studies group. Kyu-Sung Woo was Visiting Architect on the staff and Pablo Molestina was appointed Lecturer, both to work on the housing prototype design research project. Barry Zevin also rejoined the faculty for the spring term to teach a Level I studio. Hasan Kayali, who was appointed in the fall term jointly with Humanities, taught a seminar on Political Thought and

Movements in Islamic Societies. In HTC, Mr. Al-Asad taught a subject on Islamic Architecture of the 19th and 20th centuries as a Lecturer through the Aga Khan Program.

Professor Beinart was away in the fall term on sabbatical leave as was Professor Sandra Howell.

Awards: The Society of Architectural Historians conveyed the most distinguished prize in the field of history of architecture, the Alice Davis Hitchcock award, for the best book of architectural history in 1989-90 to Professor David Friedman for his book, Florentine New Towns. Ritsuko Taho received the Tiffany Fellowship in Art and Rick Bolton was voted MIT's Gyorgy Kepes Award for Excellence in the Visual Arts.

Professor Passanti was named first holder of the Clarence H. Blackall Career Development Professorship in Architectural History. He will hold the chair for the next two years. The Blackall Chair was established by the late Robert M. Blackall (MIT Class of '17) in memory of his father, a prominent Boston architect.

Professor Ranko Bon resigned from our faculty to accept appointment as Bovis Professor of Construction Management and Economics at the Department of Construction Management, University of Reading, England. The Department of Construction Management at Reading, home to the prestigious Center for Strategic Studies in Construction, is widely recognized as one of the best departments in the field. Mr. Hamdi resigned as well to take a tenured position at Oxford Polytechnic, England. Mr. Hamdi will retain a part-time association with the department in the short term, partly to sustain the Special Interest Group in Urban Settlements (SIGUS) program and partly to collaborate with us in establishing international programs. Professor Lewcock has announced his intention to leave MIT in the next academic year. A search, for his replacement as Aga Khan Professor, will be conducted with his assistance in the coming year.

OTHER

Eight department students, 2 undergraduates and 6 graduate MArch, travelled to Himeji, Japan during IAP to take part in a month-long studio on the city's waterfront. The project, under the supervision of Shun Kanda, explored and proposed alternatives for a 450 acre site between the centuries-old castle town and the Inland Sea. A site visit was followed by a two-week charrette in Cambridge, during which the MIT students worked with eight Japanese architecture and planning students devising solutions to the problem. Their final proposals were both juried at MIT and presented later in the year to public officials in Japan..

The Design for Islamic Societies (DIS) workshop in the fall term focussed on Fez, Morocco. Studios in the DIS section this year were based in Sana'a in Yemen and were directed by Professor Lewcock and Masood Khan (SMArchS '83). In the Environmental Design group, the urban design studio led by Professor Tunney Lee and Thomas Piper (SMArchS '75) examined four redevelopment scenarios for the upper Boylston district of Boston's West Fens. Among the guests of the Environmental Design Forum were Professor Bill Hillier of University College, London; John Billingham, Design and Development Director of Milton Keynes, England; Homer Russell, Boston Redevelopment Authority, Larry Bluestone, Boston Society of Architects, Martha Bailey and H.H. Smallridge, who participated in a panel discussion on the Central Artery project. The SIGUS series of three workshops this year featured, in February, the traditional market approach to housing in the third world, looking at a project in Tunis; in March, lecturers from Jimmy Carter's Georgia-based organization, Habitat for Humanity, discussing the non-governmental approach to housing where volunteers do the building; and in April, Morio Zoyula, who examined the non-market approach to housing taken by Cuba. SIGUS is headed by Reinhard Goethert and Mr. Hamdi, leaders of the Design and Housing section.

Student awards were as follows: Agis Ikonomidiz-Doumas was chosen for the department SMArchS prize for the top student in that program; Christopher Falliers and Michael Joyce shared the

Sidney B. Karofsky Prize as outstanding students entering the final year of study in the professional program; Carlos Fernandez and Timothy Mansfield were given the Francis Ward Chandler Prize for achievement in architectural design; David Yosick received the William E. Chamberlain Prize as the outstanding undergraduate; in addition, the department awarded four special undergraduate prizes for achievement in design to Steven Bull, Simon Eisinger, Jeeyoon Lim, and Priti Paul. The Alpha Rho Chi Medal went to David McCullough, for service to the department and promise of real professional merit. Chan-Li Lin received the American Institute of Architects (AIA) Certificate as runner-up and Thomas Hurt received the AIA Medal for top-ranking student graduating from the MArch program this year.

WILLIAM L. PORTER

Department of Urban Studies and Planning

INTRODUCTION

This year marked its beginning with Tienanmen Square and ended with the NATO meeting, the Soviet Communist Party Congress and the Economic Summit in Houston. While the command economies and centralized bureaucracies struggle with restructuring and opening up, the US continues to struggle with poverty and drugs, the shortage of housing, and the degradation of the environment. Among choices and decisions facing countries all over the world were: How to shift away from budgets dominated by the Cold War? How to introduce democracy, decentralization and markets into socialist economies? How to maintain equity and social justice in market economies? How to balance economic development against environmental decline? The task of the department is to help define the issues as they apply to urban planning and set the problems for research, teaching and implementation.

At this juncture, Professors Donald Schon and Philip Clay take on the responsibilities and challenge of leading the department. They will have in place a planning process to help them. For the last year and a half, in many settings and on a regular basis, the Long Range Planning Committee (LRPC) (Professors Philip Clay, John de Monchaux, Joseph Ferreria, Gary Hack, Ralph Gakenheimer, Langley Keyes, Lawrence Bacow, Donald Schon, Lawrence Susskind, Judith Tandler, and Amy Schectman, Lecturer, acting as Director) has begun to relate the day-to-day decisions of the department with a broad and long-range look at the mission of the department.

The LRPC has, so far, outlined two areas as the basis for further discussion and planning. The first is the key values that characterize the shared views of most the faculty.

Commitment to taking action in the world;

Commitment to social and political reform;

The importance of improving the quality of places and spaces;

Special interest in making institutions work.

The second is the elements of a mission statement. The department should organize its teaching, research, and interactions with the world-at-large in a fashion that will:

1. Educate professionals who will pursue our values effectively in the world and who will be able to perform expertly in certain specialized areas or roles.
2. Develop new knowledge and deliver it to the public.
3. Help sustain those institutions with goals we support.
4. Provide continuing intelligence about urban conditions and changes afoot in the way communities are functioning.
5. Develop new methods and techniques that will assist in the process of public decision-making.
6. Help improve and extend the impact of the planning profession.

7. Take responsibility for the continuing education of planners, public managers, and other mid-career professionals.
8. Take full advantage of the knowledge and skills at the rest of MIT and bring our values to the fore at the Institute.

The LRPC is continuing its work with task forces on relations with the world, MIT and the profession, all broadly defined. There will be decisions linked to important milestones such as the budget, promotions and hiring, etc.

EDUCATIONAL PROGRAMS

Both the PhD and MCP programs continue to be among the most successful programs in the country with a high ratio of applications to admissions. DUSP still attracts highly qualified students despite the expanding gap between our costs and those of our peers in state universities (e.g. UC Berkeley, UCLA, University of North Carolina). Also, our commitment to recruiting and educating minority students has been successful because of the dedication of substantial resources by the MIT administration. However, our very success has led to strains upon those resources and reduced the number of qualified minority students that we can admit. Our program in planning in developing countries was a pioneering program and continues to excel in the size and quality of the faculty and graduates. Again, accelerating costs and diminishing government support has put severe limitations on students.

The Community Fellows Program under the direction of Adjunct Professor Melvin King, has successfully gained funding from the Ford Foundation. The \$120,000 grant for 1990-91 will support, along with city governments, twelve mid-career professionals from around the country to work on issues of youth development.

The Special Program for Urban Regional Studies (SPURS) hosted thirteen fellows from Saudi Arabia, Turkey, Israel, China, Japan, Tanzania, India, Brazil, Greece and the Philippines: Dr. Gillian Hart, Senior Lecturer, was the Director.

EVENTS

The department sponsored three alumni evenings with panelists from the profession, alumni and the faculty. They were well attended with lively discussions reflecting the timeliness of the topics:

"Public Entrepreneurship - Is it in the Community Interest?"

"Redlining - Can we Correct It?"

"The Infrastructure Crisis in Developing Countries - Implications for the United States"

The department also joined with the Tufts Planning Program to sponsor the Professional Development Institute in January. It was formed to respond to alumni interest for short courses designed to gain or brush up on key skills used by planners. Fifteen workshops were offered in communications, analysing/reviewing information and managing.

Also, this year, the alumni newsletter was substantially redesigned and enlarged to become a forum for special topics and alumni news.

FACULTY

Two searches were conducted. The one in Design and Development resulted in the appointment of Lawrence Vale as Assistant Professor and the holder of the Edward H. and Joyce Linde Chair in Urban Development. The search for a faculty in planning and real estate development will be extended to 1990-91.

Visiting faculty were: in Housing and Community Development, Ronald Ferguson from the Harvard Kennedy School of Government and Richard Schramm from Tufts University; in Developing Countries, Alice Amsden from the New School for Social Research; in Design and Development, Tom Piper from the Boston Redevelopment Authority.

Visiting Scholars were: Yale Rabin from the University of Virginia; Peter Medoff from the Dudley Street Neighborhood Initiative on a grant from the MacArthur Foundation; Charles Lemert from Wesleyan University; and Reginald Griffith, the Executive Director of the National Capital Planning Commission. The faculty, as usual, were involved in research, writing, practice and community service. Some highlights follow:

- Professors Bernard Frieden and Lynne Sagalyn published their book, Downtown, Inc: How America Rebuilds Cities;
- Professor Mark Schuster was awarded a Fulbright Visiting Lecture Grant to work with the New Zealand Arts Council;
- Professor Bish Sanyal received the Rapkin writing award for the best article in Journal of Planning Education and Research.
- Lecturer Patricia Hynes published the Recurring Silent Spring and Earthright and participated in many media events around Earth Day 1990;
- Professor Joseph Ferreira was the organizer of the New England Track at the National Urban and Regional Information Systems Association (URISA);
- Professor Karen Polenske continues her work on China, participating in World Bank projects and giving a paper at the International Input-Output conference in Hungary;
- Professor Langley Keyes is co-editor of the forthcoming book, Building Foundation: Housing and Policy;
- Professor Edwin Melendez conducted research on Latins, Poverty and Public Policy at the Gaston Institute, U Mass Boston;
- Professor Lyna Wiggins is co-editor of Expert Systems: Applications to Urban Planning;
- Professor Robert Fogelson published his book America's Armories: Architecture, Society and Public Order;
- Professor Lawrence Susskind was active in conferences and workshops in international environmental dispute resolutions;
- Professor Gary Marx's book Undercover received the Outstanding Book Award from the Academy of Criminal Justice Sciences;

- Professor Donald Schon published his book The Reflective Turn;
- Professor Judith Tandler continues her work with the World Bank on the Northeast Brazil Rural Development project.

AWARDS

Jean Reisman received the AICP outstanding Student Award; Bonnie Wolf received the Charles Abrams Scholarship. The Flora Crockett Stephenson Award went to Jean Reisman and Bonnie Wolf.

TUNNEY LEE

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; to facilitate the coordination of joint, program-wide activities; to maintain a steady exchange of fiscal and substantive information between the program and the donor; and to coordinate program outreach in the Third World.

The 1989-90 academic year was marked by activities aimed at both consolidating and broadening the work of the program. Considerable time was spent improving internal communication between and among students, faculty, staff, the Harvard and MIT communities, and the public at large. An internal master calendar was circulated to better inform AKP students, faculty, and staff about AKP activities, visitors, and staff travel plans; a special newsletter was distributed among students to alert them of program activities and resources, potential jobs, and grant and scholarship opportunities and deadlines. The second issue of a program-wide newsletter, which reports on the many activities, publications, and academic and research programs, 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 launched. An international search for two Visiting Aga Khan Professors to be assigned to the University of Jordan in Amman and Dawood College in Karachi was completed as part of the AKP's Parallel Centers program of international outreach. The final prototype of the Videodisc computer system was completed and prepared for installation at the Parallel Centers. The first system was installed at the Department of Architecture at the University of Jordan in October 1989. A special one-week training program on its use was held in April 1990 for the department's students and faculty by Ms. Kim Lyon, AKP Archivist.

Three new publications were released; *Taj Mahal: The Illumined Tomb* compiled and translated by W.E. Begley and Z.A. Desai, is an anthology of 17th century Mughal and European documentary sources; *Islamic Architecture of Cairo* by Doris Behrens-Abouseif is an historic survey of the Islamic architecture of Cairo; and *Muqarnas 6* is the sixth edition of the program-sponsored annual, which represents new work in the field of Islamic art and architecture.

FACULTY

AKP policy is made by an Executive Council currently composed of Oleg Grabar (Chairman 1989-90), Aga Khan Professor of Islamic Art and Architecture at Harvard; Ronald B. Lewcock, Professor of Architecture and Aga Khan Professor of Design for Islamic Societies (DIS) at MIT; William L. Porter, Leventhal Professor of Architecture and Planning and Head of the Department of Architecture at MIT; and Francois Vigier, Charles Dyer Norton Professor of Regional Planning at the Graduate School of Design, Harvard University. Other MIT faculty during 1989-90 included Messrs. Mohammad Al-Asad, Lecturer for the History, Theory and Criticism Program; Akhtar Badshah, Lecturer/Research Associate in the DIS unit; and Masood Khan, Lecturer in the DIS unit.

ACADEMIC PROGRAMS AT MIT

The Design for Islamic Societies (DIS) component of the SMArchS program

This year, five new students were enrolled in the DIS component of the Master of Science in Architecture Studies degree program. With seven outgoing students, the unit accommodated 12 SMArchS students and one PhD student. The faculty consists of Professor Lewcock, Mr. Khan, Mr. Badshah, visiting scholars and architects, and other affiliated faculty at MIT and Harvard. Student reflection and debate focused on both practical and theoretical issues in architecture characteristic of non-Western societies. We considered appropriate responses to climate, building

materials, and building technology as well as socio-cultural attitudes and values which directly relate inhabitants to their environment. Students were encouraged to compare traditional, Islamic architectural forms and structures with those developed since the spread and application of Western ideas in modern times.

In fall 1989, first year students worked on a series of three workshops 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. This year, as in previous years, the workshops were essentially issue-oriented. Staff and students work closely together throughout the series, breaking off for short periods of time to individually explore particular issues. Together, the workshops form the introductory course, *Architecture and Urban Contexts in Islamic Societies*.

The first workshop familiarized students with the ordering and organization of Islamic and other Asian and African urban and social fabrics, and considered the relationship between the urban structure of traditional societies and of those cities or parts of cities which have developed with Western influence. In 1989 the old city of Fez, Morocco, a well-preserved example of a classical Islamic city, was selected. Its old Medina presented problems involving its inertia and the dynamics affecting it, as it is in close proximity to areas that are growing and changing due to the pressures of a larger urban phenomenon.

The second workshop considered the appropriate design of public buildings and spaces in Asian and African urban contexts together with contemporary attitudes toward monumentality, taking Louis Kahn's Capitol Complex (Shere-Banglanagar) in Dhaka, Bangladesh as a case study. The relationship of the new Kahn design to the surrounding city was studied with particular attention paid to the provision of traditional amenities as well as issues of acculturation and alienation. The students then developed a schematic design proposal to complete part or all of the Capitol Complex project, relating it to adjacent areas of the city.

The third workshop studied the differing attitudes toward infill design in the context of existing environments. In this two-week intensive workshop, students investigated a number of case studies and prepared schematic design proposals of their own.

In fall 1989, DIS continued its studio workshop collaborative venture with the College of Architecture and Environmental Design at the University of California at Berkeley. Similar case studies were run at both institutions, using the same background material and visual documentation. The aim of this parallel teaching experiment is to explore the validity of the DIS teaching approach and introduce the urban issues of the Islamic world to students in Berkeley.

In addition to the Design workshop, DIS offered three courses in the fall of 1989. *Special Problems in Architecture and Social Change: The Genesis of the Built House and Society*, taught by Professor Lewcock, reconsidered the field of architectural expression through 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 and meanings with examples from Asia, Africa, Europe, and America.

Architectural Theory and Function in Asia and Africa with a Special Reference to Islamic Societies was taught by Professor Lewcock and Mr. Khan. The course, comprised 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.

A new course aimed specifically at undergraduates, *Introduction to Architecture of Urban Neighborhoods in Transition*, was offered by Mr. Badshah. This exploratory course introduced urban neighborhoods in both the Western and non-Western worlds, relating Boston's North End to various neighborhoods in the non-Western world, particularly Sana'a in Yemen Arab Republic, Lahore in Pakistan, Fez in Morocco, and Ahmedabad in India. The

course highlighted the uniqueness of each place, pointed out its salient features, its people, the character of its urban environment and the problems facing these neighborhoods, and then focused on the architecture and architectural details, and their role in determining change.

The spring term is devoted to a studio workshop—Architectural Design in Islamic Societies—which considers a specific architectural design in a rapidly changing traditional environment confronting such issues as architectural precedence, changing urban lifestyles, and the initiation of urban rehabilitation. This spring's studio workshop, *Designing Community Facilities in Old Sana'a*, focused on the real design problem of a community health facility for the old city. Such a design aimed to serve both its intended function and to spur regeneration and rehabilitation within the city. The studio workshop addressed the design of a characteristic complex of buildings which embrace architectural and urban issues typically experienced by designers in the Islamic world today.

The spring studio workshop also included a two-week practical building workshop devoted to traditional building materials and methods still 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.

History, Theory and Criticism Program

The Aga Khan component of the History, Theory and Criticism Program in the Department of Architecture admitted one new doctoral student, Shirine Hamadeh. Mohammad Al-Asad, a recent Ph.D. recipient, offered the course, *Special Studies in the History, Theory, and Criticism of Architecture and Urban Form in the Islamic World*, emphasizing the 19th and 20th centuries.

Of the six AKP doctoral students in the program, Ms. Hamadeh was in residence in Cambridge. Khaled Asfour was conducting research in Cairo on a grant from the American Research Center in Egypt. Kara Hill was in Paris, Marseille, and Cairo on a Fulbright grant. Nasser Rabbat continued thesis research in Cairo and Cambridge, with completion of his dissertation anticipated in December, 1990. Iffet Orbay was in residence in Quebec, writing her dissertation. Richard Brotherton continued work on his dissertation while based in New York.

VISITING SCHOLARS

During 1989-90 the AKP welcomed four Visiting Scholars to the program. Hamman Tukur Saad is Head of the Department of Architecture at Ahmadu Bello University in Zaria, Nigeria. While with the AKP, Dr. Saad continued to work on the aesthetics of mud architecture in West Africa. Xiaowei Luo is Professor of Architecture at the College of Architecture and Urban Planning, Tongji University, People's Republic of China. Professor Luo pursued her work on the theory and methodology of architectural comparison while at MIT. Mohammad-Reza Haeri is a City Planner and Head Coordinating Architect at a Tehran architectural firm. He is an expert on the architecture of the ancient city of Kashan, Iran, on which he pursued his research at Harvard. Nusret Çam is Assistant Professor of Turkish and Islamic Art and Architecture on the Faculty of Divinity, University of Ankara. Professor Çam continued his work on Ottoman Turkish cities in gravures, paintings, and photos. Hugh Andrew O'Neill is Senior Lecturer in the Faculty of Architecture at the University of Melbourne, Australia. During Professor O'Neill's second stay as a Visiting Scholar at the AKP, he continued work on the traditional mosque architecture of Indonesia, particularly its vanishing timber tradition.

STUDENT SUPPORT

Tuition and living expenses for six doctoral and 12 SMArchS students at MIT and one doctoral student at Harvard were funded in whole or in part. Five students from MIT and two from Harvard were awarded summer travel grants for research in Syria, Spain, Iraq, the USSR, and Egypt. An additional three MIT students were awarded travel funds to participate in an internship and study program in Mostar, Yugoslavia. Four students were awarded travel funds for an

international rehabilitation workshop in Fez, Morocco, cosponsored jointly with the University of Rabat. In addition, one MIT student and one Harvard student were given travel grants for internships in Amman, Jordan and Lahore, Pakistan, respectively.

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 AKP's visual documentation center completed a period of testing, evaluation, and reconfiguration of its prototype Images System which integrates database management and graphics with videodisc technology. Early in the project, 3,000 of its 30,000 images had been indexed in depth; during 1989-90 the remaining 27,000 images were identified with abbreviated indexing. The prototype was installed and tested at the University of Jordan Parallel Center in Amman.

SEMINARS

The AKP co-sponsored a seminar workshop in January, 1990 on "The Southeast Asian City of the Future" with the Southeast Asian Study Group and the Indonesian Institute of Architecture. The workshop, held in Jakarta, focused on planning and architectural strategies for building new cities or parts of cities. In addition to AKP attendants, participants included senior officials from the Indonesian government and faculty members from architecture schools in Jakarta, Bandung, Yogyakarta, and Semarang.

In April the DIS unit held a day-long colloquium concerning the relation between Islamic thought and contemporary social and cultural theory as they converge upon art and architecture. The colloquium was organized such that leading scholars of philosophy and the human sciences in the Muslim world presented their thoughts on these relations with scholars of Islamic art and architecture responding.

RONALD B. LEWCOCK and BARBRO M. EK

Center for Advanced Visual Studies

The Center for Advanced Visual Studies has continued its efforts in art-science-technology with particular interests in large-scale performance, art-and-architecture and ecology.

In its 23-year history CAVS has hosted almost 175 Fellows - mostly artists - and 70 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 dedicated time and energy to the planning of a major international conference at CAVS/MIT, ARTTRANSITION '90, which will review developments in art-science - technology and new media and which will address practitioners, theorists and administrators and invite ca. 150 presenting artists and an equal number of representatives from the sciences, academe and government. ARTTRANSITION '90 follows the '75 CAVS conference, ARTTRANSITION, which preceded the four international SKY ART Conferences, '81, '82, '83 and '86. Two pre-conferences, in Baelen, Belgium, February '90, and at CAVS, April '90, have sketched program and events for the October 29-Nov. 1 ARTTRANSITION '90.

During the '89/'90 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.

Some examples of CAVS participation: "Kikeriki" - an environmental installation in "Images du Futur", Cité des Art et des Nouvelles Technologies, Montreal; "Celebration of Light", Savonlinna, Finland; "Fotografie, Wissenschaft und neue Technologien", Städtisches Kunstmuseum, Düsseldorf, Germany; "ARTEC", International Biennale of Art and Technology, Nagoya, Japan; Locarno International Film and Video Festival (Laser d'Or grand prize for CAVS); "Automnale", CNAT and City of Reims (1989/90/91).

Academic International collaborations: Kunstakademie für Medien, Cologne; Zentrum für Kunst und Medien, Karlsruhe; UNESCO, Paris.

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 to be dedicated in September '90.

Educational commitments have included undergraduate teaching ("Art and the Environment", Paul Earls; "Poetry Soiree", Elizabeth Goldring; "Environmental Holography", John Powell) and the MSVisS program (Otto Piene), thesis: "Chinese Geomany - Feng Shui" (Mei-Ling Chan Bernard).

The Eger Museum of Fine Arts in Hungary is in the process of establishing itself as a Kepes museum. CAVS is cooperating in the selection of working materials which its founder, Institute Professor Emeritus Gyorgy Kepes, has generated during his almost 30 years at MIT.

CAVS Director Otto Piene has had one-man exhibitions in Stuttgart and Düsseldorf. An exhibition and book catalog, "Gruppe Zero", celebrated his early work with his colleagues, Heinz Mack and Gunther Uecker, "30 years after" in Düsseldorf. He was part of a West German Cultural delegation and exhibition in Leipzig, East Germany, in November '89, "when the Wall came down". His work is included in "Art in the Sky", an art kite exhibition which is travelling through a series of international museums including the Museum of Modern Art, Tokyo; the "Villette", Paris; the State Museum, Düsseldorf; the Haus der Kunst, Munich; the Artist's Museum, Moscow. He has also contributed work to retrospective Zero exhibitions in Munich and Moscow.

Individual Fellows' activities: Grants to Catherine Judge/Atsushi Ogata by Fujitsu Corporation and the MIT Council for the Arts; to Mary Tsouti and Panos Kouros by Fulbright Greece and MIT Council for the Arts; to Julean Simon by the Austrian, to Nicole Stenger by the French, to Wagner Garcia by the Brazilian governments. Ellen Sebring received an Artists Foundation, Boston, major Fellowship Award in video, Grand Prize and First Prize at VideoZone, Springfield, MA and Meet-the-Composer grant from the New England Foundation for the Arts.

A sampling of exhibitions, installations, broadcasts by Fellows and grad. students: Ellen Sebring: New Television Series, PBS; World Wide Video Festival, Den Haag, Holland; De Cordova Museum, Lincoln, MA (one-person exhibition). Elizabeth Goldring: "Eye/Sight" (installation, with Vin Grabill,) in "Options" at the Washington Project for the Arts, Washington, DC. Nicole Stenger: "Images du Futur", Montreal, Centre des Arts et des Nouvelles Technologies; MIPCOM TV Festival, Cannes, France. Joe Davis, "Poetica Vaginal", Lawrence University, Appleton, WI. Paul Earls: "Eliotime" premier performance at Longy School of Music, Cambridge, MA; environment in "Images du Futur", Montreal.

Elizabeth Goldring published "Documenting Vision Loss" in New England Journal of Optometry; Todd Siler's "Breaking the Mind Barrier: The Artscience of Neurocosmolgy" is being published by Simon and Schuster, 1990.

Appointments of former and current CAVS Fellows and graduates reflect the international expansion of "art-technology-and-environment": Piotr Kowalski has been appointed Professor of New Media at the Ecole des Beaux Arts in Paris; four former Fellows will be professors at the new faculty of the Kunsthochschule für Medien in Cologne: Jürgen Claus, Dieter Jung, Bernd Kracke and Bill Seaman.

Center for Real Estate Development

The Center for Real Estate Development (CRED), founded in 1984, promotes research and education in the area of real estate development, investment, and management. The Center's major activities include a 12-month MS in Real Estate program for 35 students and research support for faculty and students.

During its sixth year of operation the Center has expanded its international network, strengthening relationships with the real estate programs at the Politecnico of Turin and the University of Amsterdam, and initiating research on the Russian housing industry through their Central State Committee. In addition, Luud Maas, President of Wilma International N.V., a long-time member firm, became the new co-chair of the Center's Advisory Committee. The Center also expanded its professional education program, sponsoring the second session of the successful Minority Developers Executive Program and developing a summer Institute for pension fund investors in real estate, as well as holding its fifth summer of Professional Development Courses.

The fifth class of 34 CRED students plus three joint degree candidates were awarded their MS degrees in real estate development in October, 1989. Miriam Maxiam, a joint degree graduate in real estate and city planning, won the first Ralph Adams Cram Prize for her thesis, "A Breakdown of Housing and Development Costs." The CRED Class of 1991 was selected in February from a strong applicant pool that was up 10 percent over last year's. The growing globalization of the real estate industry is reflected in the fact that seven members of the incoming Class of 1991 are from Canada, Europe, or Asia.

Minor changes were made to the eight core courses of the CRED MS curriculum as part of an ongoing process of revision to reflect changes in the industry. The title of Associate Professor William Wheaton's course was changed to "Real Estate Economics" to indicate the broadening of the course beyond market analysis. CRED core courses continue to be in demand by graduate students enrolled in other programs. The thesis project was changed this year to offer the additional choice of doing the thesis within the structured context of a summer course on complex real estate transactions. In addition, all students were required to take part in a thesis seminar which met once a week during spring term to develop their research and writing skills and encourage them to get started earlier on systematic and thoughtful development of hypotheses and literature reviews. A thesis option in the area of international real estate and development enabled three students to go to Russia under the guidance of Visiting Professor James McKellar to conduct research on housing.

Research by Center faculty this year focused on international issues and the performance of real estate over various phases of the business cycle. Associate Professor Bacow completed a study of foreign investment in U.S. real estate by asking whether foreign institutional owners of U.S. properties are likely to recreate in the U.S. the highly vertically integrated structure they favor in their home markets. Lecturer Marc Louargand analyzed the growth of foreign bank activity in U.S. mortgage markets, and he and Associate Professor Lynne Sagalyn completed an overview of their study of returns to real estate which examined the behavior of real estate during periods of low growth. In addition, Senior Research Scientist David Birch is in the process of updating his 1986 study of U.S. office markets.

In the area of professional education, over the past year Lecturer Louargand worked with the Pension Fund Real Estate Association to develop a summer institute for its membership. The June program for 45 participants was the first of what is planned to be an annual event. The Minority Developers Executive Program, developed in 1987 by CRED, the Minority Developers Association of Boston, and the Boston Mayor's Office, expanded to 30 participants for its second session last fall. Five of the attendees came from Washington, D.C. which supported the program enthusiastically. Almost the entire CRED faculty taught in the program on a pro bono basis. The Center continues to sponsor short summer professional development courses to help practitioners in the field keep their skills current. The offering for 1990 includes two finance courses and a negotiation seminar, all of which are attracting high enrollments as they have in the past.

In spite of the marked decline of the real estate markets in the Northeast where almost half of the Center's member companies are located, most of the founding members are still enrolled. This year six firms, representing various sectors of the industry from property management to housing joined the Center. Member firms continue to support the Center's educational program in non-financial ways by hosting case studies, taking part in classes as guest lecturers, contributing to student research, and speaking to students through the Rose Lunchbox Series and breakfast meetings organized by the student real estate club. Member firms have also supported the CRED alumni association by hosting receptions.

Semiannual members' meetings were again held in December and June. Professor Rudiger Dornbusch addressed the winter meeting on "Opportunities Abroad for U.S. Investors," and the morning speakers discussed forming alliances with foreign partners both in this country and abroad. Andrew Gutowski's (CRED '87) account of his efforts to rehab a hotel in Warsaw was particularly timely. In response to a number of requests the proceedings of the meeting were published in the same format as Center working papers. John Reed, Chairman of Citicorp, was the keynote speaker for the spring meeting which focused on "The Shifting Financial Landscape and Its Impact on Real Estate." Attendance at that meeting set a new record.

The administration of the Center will change in a number of ways. Associate Professor Bacow who has been involved with the Center since its inception will be the new director as Professor McKellar returns full time to teaching and research. During Professor McKellar's five years as director the Center became established as a locus of excellence in real estate development education and research. Mary Lou Boutwell, CRED '87, will take up a new position as Associate Director with broad responsibilities for administration, membership, and liaison with the industry. Visiting Professor Michael Wheeler is also returning to teaching full time as Senior Lecturer in the Department of Urban Studies and Planning. The position of Director of Research will remain open until the searches for senior faculty in the Departments of Urban Studies and Planning and Architecture are completed.

JAMES MCKELLAR

Media Arts and Sciences Section

In its third year of operation, the Media Arts and Sciences Section has continued to consolidate and streamline the various offerings by its affiliated faculty and research groups. Our graduate student population will stabilize temporarily at around 75, a number that is gated by the present faculty size. Accordingly, a widely-ranging search for five new junior faculty and one senior faculty is now underway. Within our student population, there is a gradual swing toward the Doctoral program as the Section matures and as more of our Master's students elect to continue their education here. The charter of the Section will come up for academic review by the School of Architecture and Planning in the Spring of 1992, an occasion toward which much of our planning effort is being focused.

EDUCATION:

Our listings in the yearly Bulletin continue to be reorganized to better express the range of our offerings, as well as the links between them. Forty-five subjects were offered by the Section this year.

Graduate:

One hundred and fifty applications for our graduate program were received last year, from which 31 were selected for admission. Our graduate student population this year consisted of 75 students (44 SM, 31 PhD, 15 women, and 4 underrepresented minorities), an increase from 64 last year, and a doubling of the last two sub-categories. Nineteen advanced degrees were awarded during the year (17 SM, 2 PhD).

Undergraduate:

This year we offered six undergraduate subjects, which were made more prominent by being gathered at the front of our Bulletin listing. One of our offerings (4.862 Holographic Imaging) has been granted standing as an Institute Lab Requirement, which considerably widens our audience within the undergraduate student body. While the Section has no official undergraduate academic program, the 106 UROP students active in the Media Laboratory maintain our lively interaction with the undergraduate student body. Of these, many do their undergraduate thesis research under our faculty's supervision. Two subjects were offered during IAP, involving three of our faculty members.

FACULTY AND STAFF:

New Appointments:

Dr. Kenneth W. Haase was appointed Assistant Professor of Media Arts and Sciences in March 1990. Dr. Haase received the Ph.D. degree in Computer Science from MIT in 1990. His interests include artificial intelligence, psychological development, machine learning and discovery, human and machine creativity, human-machine interfaces, and computer animation.

Retirements & Resignations:

Professor William F. Schreiber has withdrawn from our faculty ranks, preparatory to his retirement from EE&CS, and coincident with the move of his research activities to RLE.

Assistant Professor Bernd Girod resigned in order to accept joint positions as Professor of Computer Graphics and Animation at the University of Cologne, FDR, and Technical Director of the Academy of Media Arts, Cologne.

Honors & Awards to Faculty Affiliated With the Media Arts & Sciences Section:

Assistant Professor Glorianna Davenport was selected as the first holder of the Asahi Broadcasting Corporation Career Development Professor of Media Arts and Sciences, for a three year term.

Associate Professor Tod Machover's media opera *VALIS* was named "Opera Recording of the Year" by the New York Times, December 1989.

Professor Marvin Minsky was awarded the 1990 Japan Prize, which was bestowed by the Emperor of Japan.

HONORS & AWARDS TO STUDENTS:

Robert Sabiston's film "Beat Dedication" won first prize in the student category in the International Computer Animation Competition of the National Computer Graphics Association.

Matthew Turk was awarded the MIT-Japan Prize.

STEPHEN A. BENTON

Media Laboratory

INTRODUCTION

The Media Laboratory (Media Lab) is moving towards the completion of its fifth year in the Wiesner Building as this report is completed, with plans for a major Fifth Anniversary Celebration and Symposium on October 1 and 2, 1990. Research volume for FY'90 continued to grow to a total of \$7.5 million at an annual growth rate of 6 percent versus a previous four year average growth rate of 34 percent. This growth rate reflects the Media Lab's attainment of planned size and capacity. General and fund volume, in support of Media Lab and Media Arts and Sciences Academic Programs, also grew exceeding \$3.3 million for the year.

Sponsorship of the Media Lab expanded in all dimensions, as indicated by the list appended at the end of this section. Major new support was received from Nintendo Company, Ltd., which provided \$3 million for a fund to support research by Professor Seymour Papert into how children learn while they play. The Sony Corporation established the Sony Corporation Career Development Professorship of Media Arts and Sciences with a grant of \$750,000. Digital Equipment Corporation (DEC) approved an additional \$1.6 million equipment grant to the Laboratory.

New research sponsors during the year included BNR, Inc., Eastman Kodak Company, Goldstar Company, Ltd., SECOM Company, Ltd., Sharp Corporation, Sony Corporation, Toppan Printing Company, Ltd., and Viacom International.

New members of the Media Technology Group joining in FY'90 included BNR Inc., Citicorp/TTI, Communications Canada, CONTEL, Hitachi, IRI Group, Mitsubishi Electric Corporation, The News Corporation, Ltd., System Soft Ltd. Inc., and Seiko Epson.

All research groups within the Media Lab benefitted greatly from another round of major computer equipment gifts from Apple Computer Inc., Digital Equipment Corporation, Hewlett Packard Company, and Sun Microsystems.

The Media Lab continued to increase its dissemination efforts through events such as the conference presented by the Epistemology and Learning Group during the Annual Meeting of the American Educational Research Association (AERA) in April. At that time, "Constructionist Learning" was released bringing together a five year collection of papers, reflecting research reports, projects in progress, and essays by members of the Group. The results of Professor David Zeltzer's National Foundation (NSF) Workshop of last summer were scheduled to be released within the next month by Morgan Kaufman Publishers as "Making Their Move: Mechanics, Control, and Animation of Articulated Figures."

In a broader dissemination context, Andrew B. Lippman served as Chairman and Host of the 1990 Picture Coding Symposium (PCS), held at the Cambridge Marriott Hotel, March 25-28. The PCS is an annual meeting of colleagues and researchers in the area of picture coding and image representation, and the purpose of this event is to bring together everyone in this field to present a short description of their current work and to have the opportunity to discuss and exchange ideas. This year's event was most successful and the largest yet, with 200 participants registered from all over the world, and 130 presentations given over the three conference days.

This year was the third year 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 and Development Institute (IARDI). Lecturer Tomoyuki Suyiyama, who researched with the Music and Cognition Group, and Professor Hiroshi Yoshikawa, who worked with the Spatial Imaging Group for a year, have both returned to Japan. Hiroshi Koyangi is preparing to return at the end of the summer following a year of on the job training in Communications and Sponsor Relations. They will serve as the initial core staff for this new institution and adapt the research experience gained at MIT as appropriate.

The year also saw the creation, organization, and implementation of a major new long range international research program called Television of Tomorrow (TVOT) which replaced the Advanced Television Research Program (ATRP) at the Media Lab. TVOT embraces an end-to-end fully digital platform, from the onset, drawing little or no distinction between home computing and entertainment or between entertainment and education. The key concepts are "open-architecture" and "scalable video." The Program is designed to host ten sponsors, including three each from Japan, Europe and the United States, each coming with a different commercial perspective (i.e. publishing, telecommunications, satellite broadcast, consumer electronics, printing, etc.).

PERSONNEL AND SPACE

Professor Nicholas P. Negroponte continued as founding director of the Media Lab with an ongoing focus on strengthening the long-term sponsorship, research programs, and staffing of the Laboratory. Professor Negroponte serves as co-principle investigator for TVOT together with Mr. Lippman, the continuing Associate Director of the Laboratory. Mr. Robert P. Greene also continues as Associate Director for Administration and Finance.

The year saw the consolidation of the technical support for the Media Lab's audio, video, and personal computing operations, together with facilities management for the Laboratory in general and for the Bartos Theatre and Villers Experimental Media Facility, into a single Technical Services Group under the direction of Mr. William F. Kelley.

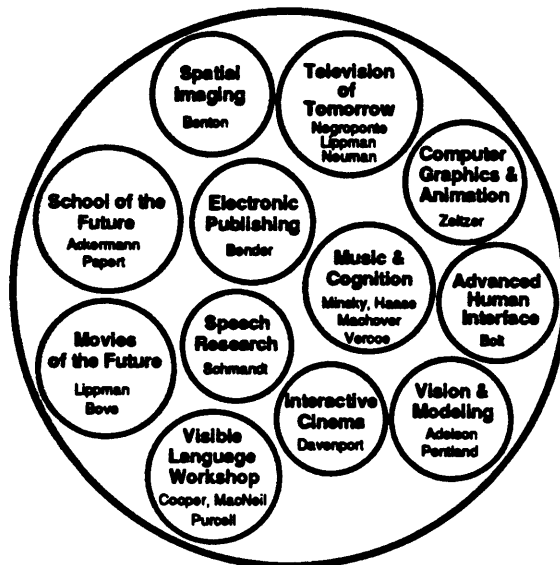
In September, the Vision and Modeling Group moved into newly renovated space which helped them to develop more of a group identity and to function more cohesively as a research group led by a team of Associate Professors Edward A. Adelson and Alex Pentland and Assistant Professor Bernd Girod. Professor Girod resigned at the end of the year to return to the Federal Republic of Germany as reported in the Media Arts and Sciences Section report.

The Media Lab's Central Systems Programming Group was greatly expanded during the year under the leadership of Mark Sausville. Anh V. Ho continues as a systems programmer with support responsibilities for Hewlett Packard workstations. He was joined by two new regular full-time systems programmers--Mr. Douglas Alan who transferred from EECS and David Blank who joined the Media Lab from Brandeis University. David Sheppard also joined the Group, part-time, with programming responsibilities for Thinking Machines Corporation's model CM II Connection Machine. Boniface Makatiani, a recent MIT graduate, has been employed by the Group for a year as a minority intern under a new program implemented this year at the Media Lab to provide training opportunity to underrepresented minorities.

The Communications and Sponsor Relations Group (CASR), also moved into newly renovated space and underwent some significant staffing changes during the year. John J. Hynes joined the Media Lab full-time with half-time responsibilities for CASR's Administrative and Financial Operations including the implementation of the Laboratory's new Intellectual Property policy and with half-time responsibilities as a Project Officer for TVOT, the DARPA program, and several other projects. Timothy P. Browne resigned as Associate Director of CASR at the end of the calendar year to accept a position with Interactive Sports and Special Events in New York City, an interactive television research consortium of eight partners including McCann Erikson and other Media Lab sponsors. Professor Patrick A. Purcell, who has served as Director of CASR for the last several years, is returning to London at the end of the fiscal year, where he will direct CASR's new European Office. "The Electronic Design Studio" which Professor Purcell co-edited is being published by MIT Press this summer. Following an extensive six month world-wide search with over 400 candidates, Dr. Chandler Harrison Stevens (Harry) joined CASR in June as the new Director. Harry, who has an undergraduate degree in Electrical Engineering from Georgia Tech and a Ph.D. in Economics from MIT, arrives with long and continuing ties to the Institute and with significant computer programming, communication, and industrial management skills that have recently focused on "cotechnology (computers and communications)." A search is currently underway for a new CASR Associate Director to round out the group.

Staff departures during the year included Michael Schrage who completed his writing assignments, Paula Hooper who resigned to pursue graduate studies in Epistemology and Learning, Saqib H. Khan whose contract was completed, and Victoria Bippart who resigned to pursue a career in film-making.

CURRENT RESEARCH



I. SIGNAL PROCESSING

1. Early and Mid-Level Vision
2. Pyramid Image Coding
3. Cooperative Perception of Shading & Reflectance
4. Micro-Movies
5. Paperback Movies
6. Combining Multiple Sources of Range & Motion Information
7. Desktop Movies

II. MEDIA TECHNOLOGY

8. Open Architecture Television -- Basic Research
9. Structural Models of Motion Pictures
10. Perfectly Scalable Video
11. Unrecordable Video
12. Optical Simulator
13. Color Alignment for Expressive Display of Information
14. Portable News
15. Font Scaling
16. Spread Spectrum Technology
17. Wide-Angle Synthetic Holograms
18. Edge-Lit Holograms
19. Holographic Color Control
20. Holographic Video
21. Common Sense Comprehension

III. HUMAN INTERFACE

22. Eyes As Output:
Eyes in Multi-Modal
Computer Dialogue
23. Knowledge Based Animation
24. Data Glove
25. Tactile Simulation/Force Feedback Joystick
26. Computers and Telephony
27. Desktop Audio
28. Back Seat Driver
29. Synthesis of Affect: Attitudes to Conversation
30. Voice Windows
31. Network Based Voice Services

IV. APPLICATIONS OF MEDIA TECHNOLOGY

32. Society of Mind
33. Animal Construction Kits
34. Storyteller Systems
35. Meta-Media, a Multi-Media Authoring Testbed
36. Topographical Typography
37. Tone of Voice Typography
38. Design Constraint System
39. Graphics for Software Visualization
40. Intelligent Assistants for Visual Problem Solving
41. Visual Information System
42. Interactive Cinematics
43. Elastic Movies
44. Advanced Interactive Mapping Displays
45. Hyperinstruments
46. Synthetic Holography for CAD
47. Holograms for Medical Imaging
48. Synthetic Performer
49. Synthetic Listeners
50. Artificial Acoustic Ambience
51. Looking At People
52. Exploratory Design and Visualization:
Virtual Manufacturing
53. Constructionism: Elementary Science Education
54. Using Computers to Combat Illiteracy
55. Children as Cyberneticists
56. LEGO/Logo

The balance of this year's statement consists of reports from projects. The ongoing research of the Media Lab extends across a wide realm of activities, which may be clustered into four broad areas. They are: Signal Processing, Media Technology, Human Interface, and Applications of Media Technology. The Human Interface listing provides evidence of media technology's role in mediating between the user & the user's information environment. Signal Processing supplies a methodological infrastructure for many of the projects in the Media Lab. Media Technology and Applications of Media Technology show the very broad spectrum of human affairs touched by this new interdisciplinary field.

I. SIGNAL PROCESSING

Modern signal processing points in the direction of channel understanding of information content and use of such knowledge to facilitate transmission. The following seven projects are drawn from cinematic, television, and telecommunication applications. The immediate achievements are representations (video, videographic, holographic, and photographic); the longer-term consequence is computer recognition and understanding.

1. Early and Mid-Level Vision (Professor Edward Adelson)

We are developing early and mid-level vision mechanisms that emulate the processing that occurs in primate visual cortex and are designing algorithms that apply them with high computational efficiency. The mechanisms are useful for edge detection, texture analysis, motion analysis, and image enhancement.

2. Pyramid Image Coding (Professor Edward Adelson)

Pyramids are multi-scale transforms that are useful in image analysis and image coding. We have previously developed pyramids using quadrature mirror filters, which give excellent image data compression. We are now developing a variant on this type of pyramid using hexagonal sampling; it leads to a transform that captures information about orientation and scale, and allows for improved data compression with very good image quality. Another useful class of pyramids is based on "steerable filters"; these will be useful in machine vision applications.

3. Cooperative Perception of Shading and Reflectance (Professor Edward Adelson and Professor Alex Pentland)

One of the fundamental problems of perception is that a given pattern in a two-dimensional image can arise from many configurations in the three-dimensional world. For instance, a light-dark edge may arise from a change in surface color, surface orientation, or illumination. We are devising a cooperative model that can disambiguate these various sources for simple scenes. The model consists of a set of specialized mechanisms, each with expert knowledge about its own domain (e.g. shape, or shading, or reflectance); these mechanisms work together to find the best interpretation of the image.

4. Micro-Movies (Walter R. Bender and Andrew B. Lippman)

Micro-movies are extremely small moving images that use time rather than size as an explanatory dimension. Complete screens of typical window systems are populated with multiple small moving images that can each become animated as they are signalled by either the user or a program. A sample application involving a synthetic "Yellow Pages" is under development in which each advertisement has a micro-movie associated with it.

5. Paperback Movies (Andrew B. Lippman)

MIT has developed a scalable representation of movies for low bandwidth compressed distribution that is useful for compact disc delivery, multiple programs on a single television channel, computer network distribution, and interactive display. In addition, we have supported the standard model under discussion at the ISO/CCITT Motion Picture Experts group. We are continuing to develop this model and participate in the international standards debate. We anticipate taking a lead role in defining the extensions to the draft standard MPEG-II. This work is being extended for cable television, computer networks, and digital broadcasting.

Work is being done on scaling the hybrid-DCT, MPEG-style images. The idea is to determine if they can be reconstructed at a different size from the encoding size. We are also working on the system requirements of networked video, developing a general movie language/protocol abstraction that will facilitate communication of moving picture information via diverse distribution networks and for decoding on diverse hardware systems.

Finally a project is underway developing real time encoding and decoding algorithms and systems for the DVI interactive system. DVI is the first (and only currently available) commercial on-line moving picture system, and we have been using it to simulate interactive presentations for video on computer and simulated low-bandwidth networks. We will continue to maintain a small effort in support of DVI as it evolves to merge with international standards and into consumer applications.

6. Combining Multiple Sources of Range and Motion Information (Prof. V. Michael Bove)

We have developed a number of methods for sensing the distance to points in a scene by combining the outputs of several image sensors (the "range camera" work), and also several techniques for estimating (both in 2-D and in 3-D) the motions of objects in a scene. As none of these methods is 100% reliable, the challenge is to combine multiple sources of range and motion data in a probabilistically optimal manner. The resulting scene description should enable more efficient data compression as well as scene manipulation.

7. Desktop Movies (Andrew B. Lippman)

Work is beginning on systems to determine the feature set needed for digital movies in workstation environments. One project under way involves creating movies automatically from an ensemble of archetypical images including actors and backgrounds under the control of a computer process rather than a fixed script. The general theme is the incorporation of independent activity at the interface, and the technical underpinnings include exploration of the representation of the images necessary for interactive assembly and image alteration. The data is stored using the same format as is used in Paperback Movies (above), but the emphasis is on interaction within the frame and alteration of sequence instead of continuous playback.

II. MEDIA TECHNOLOGIES

Media Technology is an interdisciplinary venue where new forms of information technology, hitherto researched and taught as isolated disciplines, find innovative applications in a broad spectrum of human affairs. The roles of this multi-faceted subject in projects which link audio, video and all the modalities of input/output are illustrated in the following projects.

8. Open Architecture Television -- Basic Research (Professor V. Michael Bove, Andrew B. Lippman, Walter Bender)

Open Architecture Television involves a television image format that is independent of line and frame rates throughout the system. Pictures from existing worldwide broadcast systems, film cameras, and HDTV equipment can be freely intermixed, post-produced, and displayed on receivers operating on any standard (up to 2000 or more lines), and at frame rates from 24 to 100 per second. This is ongoing work that has been described in papers and theses and has helped direct the United States delegation to the CCIR. This work is becoming central to the goals of the Committee on Open High Resolution Systems. The technical program concentrates on the temporal aspects of multi-rate television signaling and on defining signal formats that are compatible with telephone, satellite and broadcast systems. The work began in the Movies of the Future Program and is still relevant to that program but additional funding has been provided by the Television of Tomorrow program to maintain program balance.

We have been putting together a large scale demonstration of open architecture television using networks and systems available in the Laboratory and special-purpose video processing hardware under construction (Cheops). Cheops will encode and playback compressed movies from compact discs and via computer networks simulating cable television and telephone delivery systems. It is a modular architecture, the first implementation of which uses an advanced general-purpose processor and specialized chips including an image processing chip newly available from C-Cube that processes JPEG-format images in real time. In addition, other personal computers and workstations in the Laboratory will be configured to simulate a television encoding, transport, and decoding facility with a variety of program sources, distribution systems and receivers. Included will be the existing DVI equipment, personal computers, a prototype Paperback Movies Simulator and the 2000-line display system. This system will be used to explore display options, network architectures, and encoding quality, and will begin operation this fall.

9. Structural Models of Motion Pictures (Andrew B. Lippman)

Several segments of a television serial program will be selected to locate multiple views of the same set where the camera perspective has been slightly displaced as if shot with a stereoscopic imager. These two views are then used to generate three-dimensional data of the set that can segment the various elements such as furniture, walls, and actors. This data will then be used to colorize and alter the camera angles for wide-screen presentation and high resolution enhancement.

A second aspect involves entering the database of the sets used in a television program into a 3-D computer-aided design system and correlating the images actually used in the telecast with the synthetic 3-D model. The video will be used to add pictorial detail to the computer database, which will then be painted once and re-introduced into colorized or altered versions of the program.

10. Perfectly Scalable Video (Professor V. Michael Bove, Professor Arun Netravali, Andrew B. Lippman)

This project addresses compressed representations of moving images (such as Paperback Movies). The images are encoded at a single rate and then decoded at any rate up to the maximum provided by the encoder. The idea is that as the bandwidth of the decoder is increased, even by as little as one bit per second, the picture size or quality smoothly and seamlessly improves. In terms of computer displays, this allows variable network bandwidth to be used and allows the receiving computer to variably allocate resources to the image display. For distribution, this allows a channel to be dynamically allocated between high resolution images and multiple alternatives.

11. Unrecordable Video (Andrew B. Lippman)

The "Unrecordable Video" project addresses video image processing for copyright protection. Past work on generating video formats that are viewable but not recordable is being extended to include copy-protection and encryption and signature information into distributed video information.

12. Optical Simulator (Dr. W. Russell Neuman)

The Optical Simulator will allow us to test responses to a full spectrum of simulated video image qualities from below VHS quality to VHDTV and beyond. The key concept is the use of real objects to generate the best possible image through purely optical transmission onto a rear projection screen simulating a super-quality panel display. There are no fields, or scan lines at all. The image quality is limited only by the physics of the optics and the display screen itself. Screen brightness is manipulated continuously by lens size and amount of light used at the source. Contrast ratio is continuously variable by washing the rear of the display screen with varying levels of unfocused light. Screen size is a function of lens parameters. Resolution is a function of focus or the use of special lenses to simulate pixelization and scanning in an effort to vary resolution for testing purposes.

13. Color Alignment for Expressive Display of Information (Walter Bender)

This research investigates the role of color alignment in the generation of expressive energy in color signals. Central to this investigation is the formulation of color alignment and its measurement. Objective quantification of color relatedness is desirable since it frees color signals from subjective connotations. Expressive load of color messages can be predicted based on selection of color alignments. Such prescriptions can be useful in situations where automatic selection of colors for maximum information transfer is desired.

14. Portable News (Walter Bender)

This project concerns itself with both the content of a signal and any idiosyncrasies of the person viewing or using the signal. The context of the project is a news information application. We are designing multi-media data representations which are amenable to manipulation on a variety of levels, from scaling to abstracting. We are pursuing issues of image and data communication within the context of portable devices as well as very high resolution (desktop or wall sized displays). While doing parallel development within these two extremes, we will be exploring how we might "transcode" the data stream to meet vastly different communication/processing/image quality environments.

15. Font Scaling (Walter Bender)

The goal of this work is to analyze and exploit the changes that occur to characters as their scale varies, both in absolute magnitude and relative to the raster of the display device. The approach we have taken is to model character contours using energy minimizing splines. We gauge the "elasticity" or stiffness of a character by building a correspondence between normalized fonts of different point sizes and weights. Forces can then be applied to the contours which will have effect on components of character relative to the degree of elasticity of the components. We are currently investigating the application of forces for non-uniform scaling characters to improve legibility and provide device dependent grid fitting.

16. Spread Spectrum Technology (Professor Jerome B. Wiesner)

In this application, spread spectrum technology is concerned with communication over a power line bus and deals with the issue, that since power lines are designed for the transmission of electrical power and not data, load noise is very high. This project has been addressing the feasibility of establishing a two-way data transmission facility over this medium.

17. Wide-Angle Synthetic Holograms (Professor Stephen A. Benton)

A combination of distortion control by digital image pre-processing and the development of new optical techniques is making possible the production of white-light viewable holograms with an angle of view exceeding 90 degrees from side to side.

18. Edge-Lit Holograms (Professor Stephen A. Benton)

A three-step holographic process has been adapted to allow the holographic illumination to be introduced from the edge of the hologram, permitting a very simple and compact display geometry.

19. Holographic Color Control (Professor Stephen A. Benton)

A system for the chemical pre-treatment of holographic emulsion, and controlled swelling during their exposure, offers the possibility of an automatic process for full-color holographic imaging of natural and computer-generated scenes.

20. Holographic Video (Professor Stephen A. Benton)

A reduction of the information in a hologram to the minimum necessary for visual purposes has made possible the development of an acousto-optical light modulator and spinning polygonal mirror laser system for the display of moving holographic images. We believe that this is the first time that holographic images have been computed, transmitted, and displayed in real time.

21. Common Sense Comprehension (Professor Kenneth Haase)

We are developing a system to support the understanding of situations by reference to other situations which the system has previously encountered. The system uses a body of "experience" -- situations it has seen and understood -- to understand newly encountered situations. This comprehension process illuminates the new situation and enriches the systems' awareness of the sensible variations of what it has previously encountered. We are working to encode a large corpus of stories as the basis of a system whose "common sense" derives from its ability to apply a diversity of reliable paradigms to new situations. Unlike other "common sense knowledge" projects, we do not seek a uniform and consistent representation of common-sense knowledge; instead, we believe that the "source of power" in human common sense is the ability to usefully apply many distinct and sometimes incommensurable ways of looking at new situations.

III. HUMAN INTERFACE

Human Interface research in the Media Lab spans all the significant modalities of human/computer interaction, including research into combination of speech, gesture, and eye input/output. It encompasses the exploration of techniques to support capture of speech and both gestural and gaze outputs from the human user. It addresses the development of machine intelligence to interpret such outputs from the person and maps them to an appropriate response, usually some action in graphics and/or sound (including speech).

22. Eyes as Output: Eyes in Multi-Modal Computer Dialogue (Dr. Richard A. Bolt)

This research is currently exploring and evaluating eye movements in human/computer dialogue, both alone and in combination with speech and manual pointing. The emphasis is on looking behavior as evidence of interest and attention and as a means of reference.

23. Knowledge Based Animation (Professor David Zeltzer)

The long term research goal of this project is the design and implementation of an intelligent animation system which will allow non-expert users to define and control the behavior of realistic, articulated figures in complex, simulated environments. The past year saw continued development of motion control systems based on inverse kinematics and the simulation of Newtonian mechanics. These programs have been integrated into a larger software system which now supports the animation of a simulated world that is austere in the number and complexity of objects, but at the same time exhibits many of the familiar physical properties of the world around us, including mass, gravity, and simple creatures that walk and avoid obstacles on their own. The uniqueness of this program comes from its emphasis on the intelligence and physics embedded in the modelled systems, and the integration of these simulation tools with 3D interaction techniques.

24. Data Glove (Professor David Zeltzer)

This project stems from the development of novel 3D interaction techniques and has resulted in the implementation of a gesture-driven interface to a computer graphics environment, which makes use of a product known as the Dataglove. This glove, which is worn by the user, allows the computer to model the movements of the human hand. This interface for computer graphics makes it possible for users to directly manipulate virtual objects in these simulated environments.

25. Tactile Simulation/Force Feedback Joystick (Professor David Zeltzer and Professor Woodie Flowers)

The aim of this project is the development of human interfaces which provide realistic, real-time three-dimensional tactile simulation of computer-generated objects and environments. The current device takes the form of a joystick, which can move freely in three-space.

26. Computers and Telephony (Christopher M. Schmandt)

Computer workstations can provide a much needed user interface to advanced telephony functions, provided a path exists between the workstation and switch. Controlling call set-up from a user's workstation allows a greater degree of personalization and dynamic call handling. This project is being implemented in the ISDN environment of MIT's campus telephone network, using Phoneserver, a computer network interface to Basic Rate ISDN switching.

27. Desktop Audio (Christopher M. Schmandt)

This project explores software architectures and user interfaces to voice as a computer data type as well as a command channel. Its goal is to make speech ubiquitous to a range of applications, for instance, editing a telephone message to include as an annotation of a text document. Related issues include object oriented manipulation of multiple media "selection" (or "clipboard") data between processes.

28. Back Seat Driver (Christopher M. Schmandt)

The "Back Seat Driver" is a computer program that rides along with you in the car, keeping track of your current position, giving you spoken directions to the destination of your choosing. The Back Seat Driver's speech depends upon how well you follow the route, and it is prepared to make new plans if you fail to follow its instructions.

29. Synthesis of Affect: Attitudes to Conversation (Christopher M. Schmandt)

The "Synthesis of Affect" project seeks rules for expressing emotional states with synthetic speech. These rules tell how to derive abstract parameters for intonation and voice quality from a representation of affect, and how to program a speech synthesizer to convey these tones of voice.

30. Voice Windows (Christopher M. Schmandt)

In this project we are building a speech recognition interface to a window manager in the X window system. The utility of speech recognition in this context will be evaluated by studying its use among laboratory student programmers, using logging, interviewing, and video taping techniques.

31. Network Based Voice Services (Christopher M. Schmandt)

This project explores the utility of voice in a range of applications of offering services to users of the telephone network. Topics being examined include: voice mail, speech synthesis of electronic mail, access to calendars and rolodexes, and speech based user interface to call processing features such as variable call forward.

IV. APPLICATIONS OF MEDIA TECHNOLOGY

The applications of Media Technology are as varied as the technologies being assembled to serve them. The following list, drawn from education (primary through tertiary), mapping, medical imaging, transportation, and the performance arts, illustrates this variety.

32. Society of Mind (Professor Marvin Minsky)

Professor Minsky continues 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 reasoning by analogy on the basis of transforming between different kinds of knowledge representations; another aspect is a "re-duplication" account of natural language, in which grammatical forms are seen as emerging directly from expressive requirements of communication between different mechanisms inside the brain, rather than from conventions that communications between people are forced to fit. Professor Minsky has a continuing 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.

33. Animal Construction Kits (Professor Marvin Minsky)

This is a project whose context is the simulation of animal behavior, with goals of developing computational models for ethology, investigating situated action approaches to artificial intelligence, and providing an educational environment in which grade-school children can experiment with behavioral mechanisms, and create autonomous characters.

34. Storyteller Systems (Professor Kenneth Haase and Professor Glorianna Davenport)

Storyteller systems are sophisticated programs with deep and detailed knowledge of some particular domain or domains and access to "media resources" -- recorded video, sound, and text--regarding the domain. By combining these resources with synthesized graphical and textual representations, a storyteller system produces a story customized to what it knows--and what it learns -- of a listener's background, preferences, and interests. These stories emerge dynamically as the system interacts with the user; questions and criticisms yield wholly new sequences of video, sound, and explanation in reply. Such systems transform the character of publication: rather than producing epistles, one produces emissaries.

35. Meta-Media: A Multi-Media Authoring Testbed (Professor Muriel R. Cooper and Ronald MacNeil)

The Meta-Media project integrates a rich set of graphic tools and editors with searching, browsing, linking, scripting, and visualization capabilities to allow research into the new design issues emerging from real time, multi-layered information in an electronic communication environment. The planning of structured and unstructured informational multi-media pathways presents graphical design complexity and challenge for both the designer and user of multi-media information. Traditional media designers from the print, audio-visual and animation worlds provide important insights into guiding viewers' perceptual responses to information.

Work that bridges the gap between the "hands-on" world of designers and the more abstract symbolic world of programming explores spatial, temporal and relational rules and methods which rank information for the viewer, influence emotional responses, and often embody hidden aesthetics. Automatic layout and design intelligence will be required to filter data for users in every field.

36. Topographical Typography/Dynamic and Intelligent Graphics in Mapping (Professor Muriel R. Cooper and Ronald MacNeil)

The typographical and graphical conventions found in conventional mapping represent hierarchical abstractions of complex analogue information and provide the viewer with ways of comprehending information for decision making.

The goal of this project is to develop dynamic maps, typography, and graphics which have knowledge of each other, and to develop intelligent tools that allow the effective design of graphical behavior in relation to real-time dynamic data. For example, as the word SNOW moves across a terrain, it changes in size and translucency in response to real-time weather data from a satellite.

37. Tone of Voice Typography (Professor Muriel R. Cooper and Ronald MacNeil)

This project explores the relationships between the spoken and seen word. Typographical style in print has long been a substitute for sound and dynamics. The new capability of integrating them dynamically points to a new vocabulary supported by such tools as real-time scaling of text, translucency and pressure input, size-driven by pitch. For example the color, size, translucency, a style and even meaning of a word may be driven by the pitch of a sound over time.

38. Design Constraint System (Ronald MacNeil)

TYRO the (very novice) Graphic Designer's apprentice is a visual programming environment to support the exploration and evolution of graphic design concepts. The basic unit of design knowledge, the prototype, is represented as a network of constraining relations with assertion rules. Similarly, a design is a constraint network of prototypes with its set of assertion rules. The environment supports multiple simultaneous perspectives on each object (Logical, Spatial, and Hierarchical browsers), and a variation generator for exploring the design space and discovering the assertion rule break-points.

39. Graphics for Software Visualization (Henry Lieberman)

This project explores how modern computer graphic imagery can be used as a tool to help programmers visualize software. We are implementing a range of experimental debugging systems that use color, animated typography, and three-dimensional visual representation of programs.

40. Intelligent Assistants for Visual Problem Solving (Henry Lieberman)

Experts in visual domains such as graphic design are fluent in the generation and critique of visual examples. We are combining representation and learning techniques from artificial intelligence with interactive graphical editors to create a "programming by example" system to assist designers in automating graphical procedures.

41. Visual Information System (Professor Patrick A. Purcell)

The Visual Information System is an ongoing project whose primary aim is to provide the graphic workstation user with access to images on the same scale and with the same richness of provision as text users expect to access data bases and online bibliographies. The user interface at the work station now incorporates facilities for playback of video and campus cable TV in addition to the retrieval of still frames from image libraries, which still represents the current focus of the visual information system.

42. Interactive Cinematics (Professor Glorianna Davenport)

The goal of this project is to develop multimedia editing and presentation systems which offer the user flexible and provocative methods of story construction. Projects include an object oriented graphical interface for virtual editing, constraint-based video sequencing, and dynamic links for temporal media.

43. Elastic Movies (Professor Glorianna Davenport)

Explorations into the form and content of interactive cinema. Current projects include: an interactive multimedia journal, "The Elastic Charles," our hypothetical issue of the American River Magazine; documentary movies as an educational resource, "City in Transition: New Orleans 1983-1986"; and multi-track narratives.

44. Advanced Interactive Mapping Displays (Professor Edward H. Adelson, Dr. Richard A. Bolt, Professor Muriel R. Cooper, Ronald MacNeil, Professor Alex Pentland, Professor David Zeltzer)

A 3-year effort commenced in January 1989 to investigate issues surrounding mapping display technology and interaction with map displays. Focal issues for project's upcoming 3rd year are: Managing Visual Complexity of Displays; Large Format Displays; Mission Planning, XYT Processing; Multi-Modal Interaction, and "Looking at the User" -- Face Recognition.

45. Hyperinstruments (Professor Tod Machover)

Hyperinstruments is a project which attempts to define and produce what we consider to be the models for musical instruments of the future. These prototypes combine new definitions of musical virtuosity with intelligent machine understanding and music structure generation. This past year, much development has taken place to extend and enrich the Hyperinstrument systems that were used for Machover's VALIS opera, including the construction of entirely new performance systems. Our "Hyperlisp" environment was turned into a general research tool, and is currently employed by various researchers at the Media Lab and at various other centers and institutions. An automated music generation and analysis system, CYPHER, was developed and tested in a number of musical contexts. An environment was established to turn acoustic signals into "hyperinstrument" controls (MACH 5). Various music cognition studies (into phenomenon such as beat and phrase tracking) have yielded intelligent algorithms which have been incorporated into our systems. Research was conducted into turning physical gesture (notably a conductor's left-hand articulations) into real time control signals, using specifically designed hand-tracking technology. Several new musical compositions have been produced and performed throughout the world using our "hyperinstruments."

46. Synthetic Holography for Computer-Aided Design (Professor Stephen A. Benton)

The extension of advanced cues to shape in realistic imaging, such as reflections of the environment, to include the parallax of holographic images, has proven important in the effective pre-visualization of complex engineering designs, especially when combined with the wide angle of view offered by new hologram types.

47. Holograms for Medical Imaging (Professor Stephen A. Benton)

The combination of high visual quality in synthetic holograms and new developments in the "volumetric rendering" of MRI medical data makes possible the representation of very complex nested three-dimensional structures. Controlled transparency of outer tissue layers, and especially the reflection of light from them as the viewer moves, has proven important in the comprehension of their spatial relationships to deeper structures.

48. Synthetic Performers (Professor Barry Vercoe)

This work continues to demonstrate that computers can exhibit real time musical behavior remarkably like that of skilled human performers. The spectre of a live violinist being automatically accompanied by our computer-driven piano has been widely viewed on public TV, and this research continues to explore the music-cognitive issues that are encountered when we put a computer system in this position of highly sensitive human interaction. The project involves tracking human performers (finger, sound), extraction of tempo, loudness and stylistic information, then construction of control processes to manage flexible real-time audio processing.

49. Synthetic Listeners (Professor Barry Vercoe)

Audio signal separation, with a focus on polyphonic pitch detection. This research seeks to understand how humans manage multi-source audio separation with apparent ease (the "cocktail party conversation" trick), and why machines cannot. We are developing new models of digital audio processing based on the massive parallelism of the ear and auditory cortex, in the hope of enabling machines to deal with complex audio signals the way humans do.

50. Artificial Acoustic Ambience (Professor Barry Vercoe)

An investigation of electronic enhancement of a room's natural ambience by creating an "active boundary" of electronic sound reflections via a set of microphones and speakers placed around the room. The technique will utilize a new class of flat reverberators running on a central very-high-speed digital audio processor. The goal is to separate acoustics from architecture in the design of public spaces.

51. Looking at People (Professor Alex Pentland)

A project called "Looking at People" includes the following topics: (1) Tracking people's body positions as they point and move about in the work environment; (2) "Lip reading" e.g., augmenting auditory speech recognition with visual cues; and (3) Person identification, principally by recognition using the relative size and position of facial features and body parts.

52. Exploratory Design and Visualization: Virtual Manufacturing (Professor Alex Pentland)

The role of computers in the mechanical design process is currently limited to drafting and, if expert systems prove useful, helping routine design detailing. Their great potential for analysis is largely limited to checking single pieces of already-completed designs. The most glaring defect in this situation is that the critical early stages of design — where different designs are compared and the general outlines of the final design are fixed — are conducted without computer support. We argue that computers can fundamentally change and improve the design process by allowing interactive exploration of the space of valid designs. Computers can accomplish this by providing a drawing medium whose agility is comparable to pencil and paper, and which allows real-time structural and dynamic analysis of the entire system as it is being designed. We are working to solve the fundamental computational problems posed by this goal, and have developed a prototype system which has already demonstrated significant promise.

53. Constructionism: A New Opportunity for Elementary Science Education (Professor Seymour Papert)

The hallmark of this project exists as an intimate connection between the development of new technological objects and the facilitating of their appropriation by individuals and cultures in an educational setting. One such major setting is the Hennigan School, a unit of the Boston Public School system.

54. Using Computers to Combat Illiteracy (Professor Seymour Papert)

Research on how the computer presence can enter the school culture. The program includes the development of a process-control computer (the "Programmable Brick") small enough to be part of a child's scale model.

55. Children as Cyberneticists (Professor Seymour Papert and Professor Edith Ackermann)

The focus of this project deals with the concepts of control and communication in early learning. It launches a research program on "cybernetic thinking" in children, which includes both the study of elementary forms of control engineering using the Logo Brick and other modules.

56. LEGO/Logo (Professor Seymour Papert)

This project aims to create environments in which children can act like inventors. Current work focuses on the development of "electronic LEGO bricks" with microprocessors or other electronic components built inside. Just as children can build structures with existing LEGO bricks, they can build "programs" or behaviors by wiring these new electronic bricks together. Applications include the development of "cybernetic animals."

MEDIA LABORATORY SPONSORS

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
 Eastman Kodak Company
 Ford Aerospace
 General Motors Corporation
 GoldStar
 Hewlett-Packard Company
 Hughes Aircraft Company*
 International Business Machines
 Interlego A/S*
 MacArthur Foundation
 National Science Foundation
 NEC
 NHK
 NYNEX
 SECOM*
 Sharp
 Sony
 Sun Microsystems
 Thinking Machines
 Toppan
 US West
 Yamaha
 Viacom International
 Warner Brothers, Inc.

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
 Interlego A/S
 IARDI
 Matsushita
 MCA
 The Mead Corporation
 NEC
 Nintendo
 Schlumberger
 Sony
 TIME, Inc.
 The Times Mirror
 Toshiba*
 Warner Communications

Media Technology Group

Ameritech
 Apple Computer
 BellSouth
 Citicorp/TTI
 Communications Canada/ATEC
 CONTEL
 Control Data Corporation
 Electronic Data Systems/CMI
 Fujitsu Laboratories, Ltd.
 Hitachi
 IRI Group
 Lotus Development Corporation
 McCann-Erickson
 MITRE
 Mitsubishi Electric
 The News Corporation Limited
 Olivetti
 Pioneer
 Roland
 System Soft
 Seiko Epson

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 has continued to pursue the initiatives articulated in the Long Range Planning process last year and described in last year's President's Report.

The Strategic Planning Group of the School met during the Fall term to advise the Acting Dean regarding future directions and faculty appointments. During the Spring term, the Dean chaired the Group which discussed future directions of the engineering profession, the relationship of MIT to Federal and State Government and the need and opportunities for creative teaching and research initiatives in the teaching of design.

In conjunction with the Provost, the School reviewed with its Advisory Board, the future directions for the Center for Technology, Policy and Industrial Development. It was decided that the Center should continue its growth in an evolutionary way until a clear, definitive set of strategic goals and a plan for reaching these goals evolve.

Discussions for initiatives in K-12 education, a student project facility and an Institute-wide effort in telecommunications were held with groups of interested faculty. Plans for developing a student project facility and for a major telecommunications initiative are under development.

This year the School of Engineering received several gifts which will be administrated by the Dean. Ralph Cross ('33) and his wife provided funds to establish the Ralph E. and Eloise F. Cross Professorship in Manufacturing. Nam P. Suh has been appointed to the Cross Professorship in recognition of his contributions to the science of manufacturing. Finmeccanica S.P.A. funded a career development professorship, that will alternate among four departments - Aeronautics and Astronautics, Electrical Engineering and Computer Science, Materials Science and Engineering, and Mechanical Engineering. The first Finmeccanica Professorship was awarded to Steven R. Hall of the Department of Aeronautics and Astronautics. The Student Project Institute, an undergraduate initiative which will benefit all departments, received its initial gift from Martin Walker ('72).

Several funds established in the last several years were first used this year. The Martin Fellowship in Environmental Issues provided by Lee ('42) and Geraldine Martin was awarded to Henry Holgate, a graduate student in Chemical Engineering. The James H. Ferry, Jr. Fund was established by a member of the Class of 1939. The Charles E. Reed ('37) Faculty Initiative Fund, which provides seed funding for faculty in the Schools of Engineering and Science, supported its first faculty member, Professor Ain Sonin in the Department of Mechanical Engineering. Reed funds are being used to support Professor Sonin's investigation into the fluid mechanics issues associated with the application of ink jet technology to the construction of three dimensional structures.

The School also received a large gift from an anonymous donor. A portion of the gift will be added to the general endowment for undergraduate student aid. In addition, funds will be used to endow a research and education seed fund in the School of Engineering. These funds will be used to support young faculty and to encourage educational outreach. The gift will enable the School of endow two professorships and a teaching laboratory equipment fund.

THE COMMITTEE ON EDUCATION

During the last academic year the School of Engineering Education Committee focused on two principle activities. In the first, a study has been initiated to assess the opportunities for improving the educational experience of undergraduates by implementing a five-year combined SB/SM degree program, with this degree considered as the first professional engineering degree. Within the School, a major study of the issues associated with the development of a five-year degree program has been undertaken by the Department of Electrical Engineering and Computer Science (EECS) which has resulted in the preparation of a preliminary proposal for a restructuring of the undergraduate curriculum to lead to a combined SB/SM five-year degree. During the summer of 1990 a detailed evaluation of the proposal will be conducted in the EECS Department. Complementing the specific proposal in EECS, each department in the school has begun a review of issues associated with the development of a five-year program including the central issue of the role of a thesis in the five-year program. These assessments by individual departments will continue in detail in the next academic year.

The second schoolwide activity undertaken under the auspices of the Education Committee has been the preparation of a proposal to the National Science Foundation to form a coalition with six other universities (Howard University, City College of New York, Pennsylvania State University, the University of Maryland, the University of Washington, and Morgan State University) for the renewal of engineering education and its infrastructure. The theme of the proposal is to improve the effectiveness of undergraduate engineering education through a restructuring of subject material, and the development of innovative and effective methods of instruction including new types of interactive learning and teaching experiences. One objective of the effort is to develop programs which couple universities with elementary and secondary schools to attract an increasing number of women and minority students to engineering. If the coalition is selected for funding by the National Science Foundation, effort will begin intensively in the fall term of 1990 with the coalition schools to develop new undergraduate engineering education programs.

THE COMMITTEE ON LARGE SYSTEMS

During the comprehensive long range planning exercise undertaken by the School of Engineering in 1988-89, the engineering of large scale systems (LSS) emerged as an area of great interest and importance for the School in the next decade. In 1989-90 the Committee for Research on Engineering of Large Systems began deliberations under the chairmanship of Professor Daniel Roos, Japan Steel Industry Professor of Civil Engineering and Director of the Center for Technology, Policy, and Industrial Development (CTPID). The Committee members have agreed that LSS are important to MIT in three respects: 1) MIT should educate future leaders to understand and work with LSS in their later professional activity, 2) MIT should broaden its research activities to examine engineering problems in the wider scope of LSS, and 3) MIT should assume a more active public service debate on technical issues, and in some cases by speaking out on important societal issues involving science and technology.

Several examples of LSS were discussed as candidates for educational and research activities including telecommunications, energy, environment, global change, and infrastructure. The Committee examined two on-going initiatives within the School of Engineering that serve as models for how the School can build upon its technological base and broaden its perspective. These were the Leaders for Manufacturing Program and the activities within CTPID. The Committee considered several LSS initiatives including: a faculty seminar to further consider issues related to LSS and to develop a two-term subject in LSS, joint research projects between engineering departments and CTPID, initiation of an Institute-wide project in LSS, the development of "context sequences" of subjects that consider particular technical issues from different viewpoints, the revision of existing subjects to include factors relevant to LSS, and the creation of a continuing technical education program for government officials.

AWARDS

This year the School established the Amar Bose Award for Excellence in Teaching. The first recipient was Professor August Witt of the Department of Materials Science and Engineering. Professor Witt was cited for having formulated and taught one of the most successful freshman subjects in recent memory, 3.091 Introduction to Solid State Chemistry. The Bose Award stands as a tribute to one of the School's finest teachers, Dr. Amar Bose, Professor of Electrical Engineering and Computer Science and founder of the Bose Corporation. The award may be given annually to a faculty member whose teaching contributions over an extended period of time are characterized by dedication, care, creativity, and inspiration to students and colleagues.

Each year the Office of the Dean of Engineering presents two awards to graduating seniors. They are:

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: Nathan S. Abramson, EECS; Joseph R. Babiec, Jr., EECS; Jose L. Melendez, EECS; Timothy Rueger, EECS; D. Shalon, Mechanical Engineering; Athanassios Siapas, EECS; and Kimo Y. F. Tam, 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 two Chemical Engineering students; Kyra R. Witt, and George W. Poulos. Both students conducted research for their theses in the Energy Laboratory.

ENROLLMENT

Undergraduate enrollment in the School decreased again this year by about 54, with decreases in Electrical Engineering and Aeronautics and

Astronautics, offset somewhat by increases in Chemical Engineering, Civil Engineering, and Mechanical Engineering. Graduate enrollments decreased by about five.

ENGINEERING INTERNSHIP PROGRAM

For the summer of 1990, 44 sophomores have been placed in the Engineering Internship Program making the total enrollment 122. There are 29 participating companies.

AFFIRMATIVE ACTION

Recruitment of underrepresented minorities for faculty positions continues to be extremely difficult. During the past nine years three underrepresented minorities joined the School's faculty. In the same period, however, three have resigned their positions.

This year, nine new faculty were hired, one of which is a woman.

The number of women faculty in the School has grown steadily over the last decade, from ten in 1980 to an expected 17 in 1990. Women now constitute approximately 5 percent of the School's faculty. During the past nine years faculty positions were offered to 27 women (16 percent of all faculty offers). Fifteen women accepted offers, 11 declined. One offer is still under consideration.

MINORITY INTRODUCTION TO ENGINEERING AND SCIENCE

In the summer of 1990, 69 high school juniors will attend the MITES Program (up from 52 in 1989). 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 Professor Douglas A. Charnichael and coordinated by Mr. William Ramsey.

FACULTY

The School welcomed nine new faculty this year. With 20 departures, the School's faculty declined by 11.

During the year, Professor Jack L. Kerrebrock resigned as Associate Dean after serving as Acting Dean between June 1 and December 31, 1989. The School is greatly indebted to Professor Kerrebrock for his energetic, creative, and active leadership. Professor Jeffrey Shapiro was appointed Associate Head of Electrical Engineering and Computer Science effective July 1. Professor Eugene E. Covert resigned as Head of Aeronautics and Astronautics. He is succeeded by Professor Earl M. Murman who will also continue as Director of Project Athena during 1990-91.

GERALD L. WILSON

Department of Aeronautics and Astronautics

The 1989-1990 academic year started with the arrival of 262 undergraduate and 215 graduate students and the beginning of our NASA Space Grant. These events were followed shortly thereafter with a memorable celebration of the department's 50th anniversary. The year concluded with the graduation of 90 Bachelors, 67 Masters, and 11 Doctoral students, the retirement of three departmental stalwarts, and the appointment of Professor Earli Murman as Department Head on June 1, 1990, replacing Professor Eugene Covert. In between these events were many noteworthy accomplishments by our faculty, the always remarkable achievements of our students, and the exciting activities of our research laboratories.

SPACE GRANT

MIT was selected by NASA as a Space Grant College and was awarded a five year grant on September 1, 1989. Professor Daniel Hastings is the director of the program. The major purpose of the grant is to attract more students to pursue graduate level education in space sciences and space engineering. Undergraduate students are involved to introduce them to these fields. During the Academic Year 18 students were supported under the UROP program and 29 undergraduate students were placed in summer jobs in aerospace companies. An undergraduate seminar subject 16.S26 Modern Space Science and Space Engineering was offered in the spring term. Chris Blanc was selected for the Hughes Research Laboratory Award for his outstanding academic achievement. Four graduate fellowships were awarded to students for the 1990-91 academic year. A highlight of the spring semester was a seminar by Dr. William Lenoir, NASA Associate Administrator for Space Flight.

50th ANNIVERSARY CELEBRATION

In the Spring of 1914, MIT awarded its first SM degree in Aeronautics to Jerome C. Hunsaker. On July 1, 1939, the Department of Aeronautics became an independent Department in the School of Engineering at MIT. Prior to this date, Aeronautics had been a division of Mechanical Engineering, an independent educational unit reporting to the President of MIT, a division of the Physics Department, and originally part of the Naval Architecture and Marine Engineering Department.

To celebrate these events, the Department and about 300 of its alumni met September 14 and 15, 1989. The celebration opened Friday with a summary of the contributions of MIT to Aeronautics and Astronautics given by H.G. Stever, a former faculty member in the Department. On Saturday morning, Professor Walter Hollister arranged a program on the history of the Department. The clear favorite was Fay Taylor's discussion of the early history from 1928-1930. That afternoon, a seminar on Engineering Education was held. The celebration was ended with a banquet. Professor David Akin reviewed his very successful EASE program, a research project demonstrating man's ability to erect structures in space.

HUNSAKER PROFESSOR

Professor Jason Speyers of UCLA, an international authority on control theory, was the Jerome C. Hunsaker Visiting Professor for the Fall semester. His Martin Minta Lecture titled "Guidance, Control and Estimation of Aerospace Systems" was presented at MIT in the spring to a sizeable audience.

FACULTY NOTES

With the retirements of Professors James Mar and Norman Ham and the departure of Professors David Akin and Belgacem Jery, the faculty complement as of June 30, 1990 was 20 Full Professors, seven Associate

Professors, and four Assistant Professors for a total of 31. The Department also has three adjunct Professors. Noteworthy milestones and accomplishments of various faculty members follow.

Professor Harold Alexander was selected as the recipient of the School of Engineering Bradley Foundation Development Chair, a two year appointment with an annual \$60K discretionary fund.

Adjunct Professor Richard Battin was elected as an Honorary Fellow of the AIAA and delivered his von Karman Lecture "A Funny Thing Happened on the Way to the Moon" to 13 AIAA Sections around the US.

Professor Covert concluded his 5 year tenure as Department Head on May 31, 1990 and returned to the teaching faculty in the Fluid Mechanics Division. He received the AIAA Ground Testing and Simulation Award for innovation and creativity in developing new ground testing techniques.

Professor Edward Crawley was promoted to Full Professor and became head of the Structures, Materials, and Aeroelasticity Division. He was elected an Associate Fellow of the AIAA.

Professor John Dugundji received the Graduate Student Council Teaching Award for Course 16.

Professor Alan Epstein was promoted to Full Professor.

Professor Michael Giles was promoted to Associate Professor and became director of the Computational Fluid Dynamics Laboratory.

Professor Steven Hall was selected as the first recipient of the Finmeccanica Career Development Chair in the School of Engineering.

Professor Ham retired at the end of the academic year completing 28 years as a Departmental faculty member. Professor Ham is a recognized expert on helicopter rotor aerodynamics and vibrations, a topic he will continue to study as Professor Emeritus.

Professor John Hansman was elected as an Associate Fellow of the AIAA.

Professor Jack Kerrebrock completed his tenure as Associate Dean of Engineering and started a sabbatical year at the California Institute of Technology.

Professor Daniel Hastings was promoted to Associate Professor with tenure and launched the Space Grant program.

Professor Paul Lagace was promoted to Associate Professor with tenure, became director of the Technology Laboratory for Advanced Composites, and was appointed as Executive Officer of the Department for one year beginning June 1, 1990. He was a co-recipient of the Everett Moore Baker Award for Excellence in Undergraduate Teaching.

Professor James C. Mar retired on June 30, 1990 after 52 years at MIT, starting with his arrival as an undergraduate in the fall of 1938. Professor Mar's achievements are numerous. In the recent past, he founded the Technology Laboratory for Advanced Composites (TELAC), co-founded the Space Systems Laboratory (SSL) with Professor Emeritus Rene Miller, and was Department Head from 1981-1983. He is considered the expert on aging of aircraft structures.

Professor Earll Murman accepted the EDUCOM/NCRIPAL Distinguished Engineering Higher Education Software award on behalf of the fluid mechanics faculty for the development of the TODOR courseware for enhancing the teaching of fluid mechanics.

Adjunct Professor Rudrapatna Ramnath was elected as a Full Member to the International Academy of Astronautics, Paris, France.

Professor Andreas von Flotow was promoted to Associate Professor.

Professor Sheila Widnall received an honorary degree from Smith College.

Professor Larry Young was selected as the First Space Sciences Lecturer for the American Physiological Society and delivered a talk entitled "What we need to know before we go to Mars".

Allan Shaw retired from his position as a technical instructor after 38 years as an MIT employee. Mr. Shaw headed up the staff teaching 16.621 and 16.622 Experimental Projects I and II and shepherded many a student through their project experience.

UNDERGRADUATE PROGRAM

As shown in the table below, the undergraduate enrollment decreased this year to a level about the same as it was in the first half of the last decade.

Undergraduate Enrollment over the Last Seven Years

	<u>1983-4</u>	<u>1984-5</u>	<u>1985-6</u>	<u>1986-7</u>	<u>1987-8</u>	<u>1988-9</u>	<u>1989-90</u>
Sophomores	100	99	106	120	96	103	75
Juniors	81	90	92	103	118	94	87
Seniors	81	93	106	98	105	130	104
Totals	262	282	304	321	319	327	266

The current fraction of women in the graduating class is 0.25 which is higher than last year's fraction of 0.16. The current average women's enrollment for all three classes is 0.23.

Mr. Michael Simon Valdez was selected for the Doolittle Scholarship Award. His outstanding academic record and contributions to the department made him the successful candidate.

Andrew Lewin '91 won the best undergraduate paper award for the Northeast Region of the AIAA, and will travel to Reno, Nevada in January 1991 to present his paper entitled "A Rigorous Testing Method for Control Systems" in the national competition.

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 winners are:

Charrissa Y. Lin	'90
James K. Kuchar	'90

JAMES MEANS MEMORIAL PRIZE

For excellence in Flight Vehicle Engineering

Marc A. Schafer	'90
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For excellence in Space Systems Engineering

Fred G. Kennedy III	'90
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ADMIRAL LUIS DE FLOREZ AWARD

Awarded to undergraduates who have demonstrated "original thinking or ingenuity" in Aeronautics and Astronautics. This year's winners are:

Juan J. Alonso	'91
Brett P. Masters	'91
Marc S. Block	'90
Fred G. Kennedy	'90
Shawn A. Birchenough	'90
Christopher A. Lentz	'90
Carl A. Blaurock	'91
Mohanjit S. Jolly	'91
Robert W. Grundmeier	'91
Laurie S. Hiyakumoto	'91

UNIFIED ENGINEERING AWARD

Charrissa Y. Lin	'90
Harald Weigl	'90

ANDREW G. MORSA '87 AWARD

For demonstrated ingenuity and initiative in the application of computers to the field of aeronautics and astronautics

Shirley Lee	'90
Harald Weigl	'90

About 1/3 of the faculty continues to be actively involved with freshman in one way or another. We are pleased that the department's commitment to this important activity remains strong.

GRADUATE PROGRAM

A total of 305 applications were received for the Fall 1989 term. Out of this number 143 were admitted and 75 accepted the offer of admission. Enrollment for Fall 1989 included 142 SM, 71 PHD, and two EAA for a total of 215 students. Enrollment for Spring 1990 was 205 including 133 SM, 70 PhD, and two EAA degree candidates. There were 10 new graduate students out of 13 admitted from 39 applications received. Eleven PhD and 67 SM degrees were awarded in 1989-1990. Funding for graduate students is summarized in the table below.

	Fall 1989	Spring 1990
DOD Fellow	1	1
NSF Fellows	7	7
AFRAPT Fellows	6	9
Other Fellows	5	5
Draper Fellows	21	23
Research Assistants	134	122
Teaching Assistants	8	7
Total Funded	182	174
Total Enrolled	215	205

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 and hazardous weather avoidance. The information management activities include studies of the dissemination of hazardous weather alerts and ATC clearance amendments 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 escape procedures which include lateral maneuvering and aircraft ice accretion studies. A novel technique has been developed to remotely detect ice on helicopter rotor blades through IR emissions which result from latent heat release during ice accretion.

Computational Fluid Dynamics Laboratory (CFDL)

Director: Professor Michael Giles

Fourteen graduate students, three faculty and a research engineer are pursuing the development of algorithms and methods for computational aerodynamic modelling of aircraft, rotorcraft, and turbomachinery flows. The main event of the year was the development of visualization software to run on the new generation of powerful graphic supercomputers. The software includes arrays of "electronic probes" for extracting visual and quantitative information from large computational data sets for unstructured and structured grids. A two-dimensional version VISUAL2 and a three-dimensional version VISUAL3 were developed and released outside of MIT. Professor Giles took over as Director of the CFDL from Professor Murman on June 1, 1990.

Flight Transportation Laboratory (FTL)

Director: Professor Robert Simpson

Research areas in FTL for the year 1989-1990 were airline revenue management systems, airline computer scheduling systems, and automated decision systems for ATC operations. There were 12 students involved in seven research projects. The MIT/Industry Research Consortium expanded as Air Canada, Swissair and Cathay Pacific Airlines joined the program. This is due to the success of FTL research in creating forecasting methods and optimizing seat allocation algorithms for Airline Revenue Management. Systematic, in-service tests on airline reservation systems during the year have indicated these methods can be worth several million dollars per month in incremental revenue. In ATC automation, a Ph.D. thesis by Michael Sadoune demonstrated that by combining expert systems software technology and parallel processing, it is possible to generate conflict-free, four-dimensional planned flight paths for aircraft arriving (and departing) in the terminal area which can be quickly updated and responsive to constraints imposed by the ATC controller.

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. Specific application for such concepts has resulted this year in first of a kind experiments showing dynamic control of compressor surge using a tailored system structure and active (feedback) control of compressor rotating stall. 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.

In the past year, we have brought on line two new facilities. One is a closed loop pump facility especially designed to examine techniques for alleviating pump noise on ships. The second is a unique facility designed to provide a controlled, swirling, transonic entry flow into an (actual engine size) discrete passage diffuser for an aircraft centrifugal compressor.

The Laboratory has also taken steps to strengthen our long-term synergistic collaboration with industry and with the Whittle Laboratory at Cambridge University, initiating a new three-way (MIT/Cambridge/GE) joint research program that will make use of the outstanding experimental facilities at the GE Aircraft Engine Group.

Man Vehicle Laboratory (MVL)

Director: Professor Laurence Young

Members of the Man-Vehicle Laboratory have been busy during the past academic year in preparation for two spaceflights scheduled to carry three MVL experiments next academic year. The first dedicated life sciences flight (Spacelab Life Sciences-1) on shuttle STS-40 will rely some of our visual-vestibular interaction experiments. The first International Microgravity Laboratory flight, currently scheduled for the end of 1990, will include a human performance and anthropometry experiment which Professor Harold (Sandy)

Alexander has taken over from Professor Bussolari and a test of the vestibulo-ocular reflex under Dr. Charles Oman. The Lab's principal expert system activity, "PI-in-a-box", is up to full strength with the recruitment of Dr. Rajiv Bhatnagar as Research Scientist in our Laboratory and the addition of two more engineers to work with our colleagues at NASA/Ames. This project, to provide an expert system on-board advisor for astronauts performing life science experiments, received its first preliminary test in conjunction with the simulations for the SLS-1 rotating dome experiment.

Space Engineering Research Center (SERC)

Director: Professor Edward Crawley

The objective of the Space Engineering Research Center is to develop and disseminate a unified technology of controlled structures. During the last year the size and scope of SERC efforts grew rapidly. Fabrication of the first facility class experiment was begun. This consists of a 3.5m tetrahedral truss model of a space based interferometer. The objective of this test article program is to develop the ability to control optical path length to nanometer precision. Designed in conjunction with space scientists from MIT, Harvard, and JPL, it is a unifying focal point of student and faculty research. Other major projects in the lab include work on flexible articulating robotic and space structures, and preparation for two shuttle flight experiments MODE and MACE. All total, eight faculty, 30 graduate students and a like number of UROPers, drawn from the Departments of Aeronautics and Astronautics, Electrical Engineering and Computer Science, and Mechanical Engineering participate in SERC.

Space Systems Laboratory (SSL)

Director: Professor James Mar

This year was one of transition, as the Space Systems Lab prepared for the departure of Professor Akin and his research efforts. The year started with the development of the *Skidbladnir* reentry vehicle, designed to gather data on the ParaShield thermal protection system concept. The spacecraft was designed and constructed by MIT students over a period of five months, and was onboard for the launch attempt of the American Rocket Company vehicle on October 8, 1989. The spacecraft survived the failure of the launch vehicle, and is now back in the SSL awaiting refurbishment for another launch. The neutral buoyancy research of the lab was extremely active, with the completion of six theses relying on data collected underwater in the MIT Alumni Pool. This included the development of a modular manipulator, up to 50 ft. long, advanced acoustic sensors for underwater navigation, and quantification of human force capabilities in a simulated microgravity environment. Five non-neutral buoyancy theses were also completed, including the development of advanced control algorithms for endpoint force control of compliant drive manipulators, and the creation of a software laboratory for advanced neural network control systems. Professor Alexander's research reached full gear this year, with the completion of a thesis on machine vision applicable to automated rendezvous and docking, as well as the initiation of a number of research efforts into vision systems and space simulation environments.

Technology Laboratory For Advanced Composites (TELAC)

Director: Professor Paul Lagace

Over 50 students were involved with TELAC during the June, 1989 to June, 1990 time period. This included 16 graduate students, 25 UROPers, and a number of students in 16.621/2 who performed their projects in TELAC. In addition, we were host to a visiting doctoral student from the University of Pisa who worked with other students and is producing a report on the research he has conducted at TELAC during the past six months. Major research accomplishments include the extension of the capability to predict delamination initiation in composites to the case of a hole in a structure, and the performance of critical damage tolerance and damage arrest experiments in pressurized composite cylinders simulating fuselages. A thermoplastic manufacturing facility was completed this year and is now operational. This extends the capability of the

laboratory to these new materials. Further work has been done on the impact facility and the impact device, known as FRED, as several requests have come from around the world for plans for this device so that similar devices can be built. During the year, the Laboratory has totally committed to Macintosh computers and this conversion is ongoing. The biggest news of the year in TELAC is a rather sad one: the founder of TELAC, Professor James W. Mar, retires at the end of June. He has been much of the inspiration behind the lab in its early years and his presence and contribution will be sorely missed by faculty and students alike.

Wright Brothers Facility (WBF)

Director: Professor Eugene Covert

The operation of the Wright Brothers Facility has involved three different graduate students (one completed his Masters thesis) and about a dozen undergraduates. Of a total of eight different major wind tunnel programs, there were four pedestrian level wind studies. A major study for the McDonnell-Douglas Aircraft Company, two studies for Lincoln Laboratory, and a basic study of the effects of snow and Reynold's number on the galloping response of cylinders for the Raytheon Company. Frank H. Durgin, Associate Director of WBF, has published one paper in Building and Environment. Four others are in press in the International Journal of Wind Engineering. Also, he has presented a paper at an ASCE meeting and is chairman of an ASCE task committee on standards for wind tunnel testing. Professor Covert became director of WBF on July 1, 1989 upon the retirement of Professor Judson Baron.

EARLL M. MURMAN

Department of Chemical Engineering

The Chemical Engineering Department moved ahead rigorously on many fronts during the 1989-1990 academic year. Developments included new emphasis on undergraduate and graduate education, a banner year for our doctoral program, new accomplishments in research, and a significant emphasis on faculty recruiting. The Department also enjoyed a very successful year of fund raising from our alumni and corporate foundations.

A major educational emphasis in the Department was the expansion of computing in both our undergraduate and graduate curricula. Utilizing the funds from a generous bequest from Lieutenant Colonel Arthur M. DeGregory '34 we established the Arthur M. DeGregory Computer Laboratory for use by members of our Department. Professor Robert C. Armstrong, the Department's Executive Officer, arranged for the distribution of Athena workstations to interested faculty and departmental personnel for aiding in instruction and educational programming.

The School of Chemical Engineering Practice continued its vigorous level of operation under the new leadership of Professor T. Alan Hatton, Director, and Professor Jeffrey L. Feerer, Associate Director. The graduate programs in the Department continued to draw top students from around the world. The number of doctoral degrees awarded this year, 42, was one of the highest in the nation. The Practice School Master's Degree continues to be a popular way for students to begin their graduate career; 57% of the current doctoral student population went through the Practice School Program. Although the senior class is the smallest in the last decade, sophomore enrollments and the projections from the freshman class show that interest in the undergraduate program is returning to previous levels.

The fund raising campaign with a goal of \$8 million for endowment of fellowships for the Practice School was completed this spring thanks to a generous donation of \$2.3 million from David H. Koch, Vice President of Koch Industries and an alumni of the Practice School. The MIT Corporation voted to name the program the David H. Koch School of Chemical Engineering Practice in his honor. Plans are underway to continue attempts to raise fellowship endowment by soliciting corporate sponsors.

Klavs F. Jensen joined the Department in the Fall of 1989 as the Joseph R. Mares Professor of Chemical Engineering. Klavs is an expert on the chemical reaction engineering of advanced materials, especially in chemical vapor and plasma enhanced processing systems. He has started research and teaching in these areas and was awarded a joint appointment with the Department of Materials Science and Engineering at MIT. After a year-long search, the Department has hired Jonathon G. Harris as the Herman P. Meissner Assistant Professor of Chemical Engineering. Jonathon was trained in theoretical chemistry at the University of Chicago and has research interests in the theory of inhomogenous liquids, especially polymer and surfactant films and colloidal aggregates. He will enhance our faculty working in colloidal systems, polymers, and biochemical applications.

These new faculty join colleagues who are nationally recognized for their achievements. Special recognition this year has gone to several faculty members: Professor Robert S. Langer, the Germeshausen Professor of Chemical and Biomedical Engineering, was inducted into the National Institute of Medicine and was awarded the Professional Progress Award by the American Institute of Chemical Engineers; Assistant Professor Karen K. Gleason won the prestigious Presidential Young Investigator Award of the National Science Foundation and the Young Investigator Award given by the Office of Naval Research.

UNDERGRADUATE EDUCATION

The following table shows the trends in undergraduate enrollment:

	85-86	86-87	87-88	88-89	89-90
Sophomore	49	43	38	47	60
Junior	69	49	36	36	46
Senior	54	65	55	47	34
TOTAL	172	157	129	140	140

The sophomore enrollment has continued to increase from the minimum of 38 experienced in '87-'88 and is now just within the range of 60-80 students per year that we feel is optimal. The sophomore class size for '90-'91 is projected to be about the same as this year, perhaps in the low 60s. Work was begun this year to revitalize the Chemical Engineering undergraduate required laboratories, 10.26 and 10.27; this is being overseen by Professor Jeffrey L. Feerer. Plans include the installation of one major new experiment in these laboratories each year over the next five years; a new pressure swing absorption experiment is the first in this plan. The combination of the revitalized project laboratories and the Integrated Chemical Engineering subjects introduced two years ago provide an excellent practical component to our undergraduate program. In addition to the laboratory revitalization, significant effort has gone into integrating computers into the undergraduate educational experience as described below.

Integration of Computing into Chemical Engineering Education

Our new Introduction to Computing subject 10.001 was offered for the second year and continues to exceed our expectations in popularity. Approximately 150 students took 10.001 during IAP alone; approximately one third of these were freshmen. We believe this indicates a strong desire by many students to use IAP productively, and that 10.001 during IAP provides an ideal setting for learning to use computers.

In order to utilize computers in the curriculum beyond this introductory subject, we recognize that faculty must be facile with the Athena environment. With help from Project Athena, we placed Athena workstations in nearly every Chemical Engineering faculty member's office this year. Training has been provided by Athena and Chemical Engineering Department staff on the basics of using these workstations. In addition, the Department has hired a programmer, Chris Craig, joint with Project Athena, to aid our faculty in developing educational applications for Project Athena. We have found splitting Chris Craig's time with Project Athena to be an appropriate model, because it provides us with a programmer who is up-to-date on the Athena environment.

Two educational computing projects have already been completed by Mr. Craig and another is underway. The first is the porting of in-house graphics software to the Athena environment. The result is a scientific plotting program which can provide publication quality graphs, contour plots, and text slides and runs with the standard Motif interface that the undergraduates learn. We plan to teach the use of this program to 10.001 students beginning next year so that they will have it for use during their undergraduate career here. A second project involved the successful porting of several quantum chemistry programs to Athena for our new subject 10.652. These provide students with the tools to make ab initio calculations of chemical reaction rate constants.

We are presently making arrangements to port a process invention program (PIP) to Athena for use in the Continuous Processing Module of our Integrated Chemical Engineering (ICE) subject. During the pilot testing of the ICE modules this year, we were able to assemble a cluster of PC's for students to run PIP. Although this worked well for 10-20 students, it is clearly not feasible for the 50 students expected next year. The publisher of the program has agreed to release the source code to us, and we expect Chris Craig to begin the porting process in July. The existence of Project Athena and its staff have been instrumental in our being able to acquire this source code.

GRADUATE EDUCATION

The following table shows graduate enrollment from 1985-1990:

	85-86	86-87	87-88	88-89	89-90
Masters	72	77	65	54	62
Doctoral	148	151	169	179	158
TOTAL	220	227	234	233	220

The total for 1989-90 includes 90 foreign students, 35 female students, and 8 minority students (not including Asian Americans).

The total graduate enrollment has begun to decrease from a high of 234 in 1987-88. Based on graduate admissions data for the last several years, we believe that the total graduate enrollment will stay nearly constant over the next several years.

School of Chemical Engineering Practice

Professor T. Alan Hatton became the Cambridge Director of the Practice School, with responsibilities for long-range planning and overall direction for the Practice School operations. Professor Jeffrey L. Feerer returned to Cambridge after completing three years as a Station Director, and he is coordinating the operation of the Practice School Stations.

This year 34 students participated in the Practice School program at four stations: Dow Chemical at Midland, Michigan; General Electric at Albany, New York; Syntex Chemicals at Boulder, Colorado; and Chevron at Richmond, California. We are returning to Richmond this summer, which will be our second summer in California. The Director of the Richmond Station will be Mr. Fred Vorhis, who worked at Chevron for ten years and is currently a Senior Lecturer at the University of California, Berkeley. Our station at Midland has completed its fourth year of operation, currently with Professor Paul Webley as Director and Vic Barocas as Assistant Director. We have been at the Albany Station for twelve years now, currently with Professor Keith Bailey as Director and Philippe Matthys as Assistant Director. Professor Bailey joined the faculty of the Practice School after working at BASF for two years.

We are pleased to report that the Practice School Fellowship Endowment will reach the goal of \$8 million with a generous donation pledged by David H. Koch '62. We now will be able to award fellowships to Practice School students to pay tuition and a stipend while they take graduate course work in Cambridge. In honor of his donation, the MIT Practice School will become the David H. Koch School of Chemical Engineering Practice starting July 1, 1990.

RESEARCH HIGHLIGHTS

Biotechnology Process Engineering Center (BPEC)

Mammalian cell cultures are presently employed for the manufacturing of complex compounds which are used in a variety of diagnostic and therapeutic applications, including the production of vaccines, monoclonal antibodies, thrombolytic agents, factors for the treatment of hemophilia, and others. Key to the development of the above processes are systems for the cultivation of mammalian cells which are versatile so they can be used with a variety of cell lines, robust to minimize the impact of external perturbations, and efficient in the sense that they can accommodate maximum cell densities and specific cellular productivities. The above constitute the goals of the research undertaken in Professor Gregory Stephanopoulos' laboratory under the auspices of the MIT Biotechnology Process Engineering Center (BPEC). Specific accomplishments to date include (a) the synthesis of macroporous ceramic microcarriers which are used as substrates for cell growth; such microcarriers are biocompatible in the sense that they allow unhindered cell growth and product expression; (b) the analysis of the simultaneous processes of intraparticle diffusion, convection and depletion of oxygen and subsequent optimization of pore size and particle diameter for maximum utilization of cellular activity; (c) the development and optimization of a packed-bed bioreactor system with macroporous ceramic microcarriers which protects the cells from adverse external effects such as shear, while ensuring adequate oxygen supply in a prolonged continuous operation; and (d) testing of such bioreactors with industrially important cell lines. The developed system is equally applicable for the culturing of suspension as well as anchorage-dependent cell lines in a static or continuous perfusion mode. The use of this bioreactor system with cells possessing the property of regulated secretion (also investigated in this research group), promises to lead to novel integrated cell-culturing systems that combine in a unique way the cultivation and product purification steps of a biological process.

Artificial Intelligence in Process Engineering

The Laboratory for Intelligent Systems in Process Engineering (LISPE) in the Department of Chemical Engineering entered the fourth year of its research and educational activities. Under the direction of Professor George Stephanopoulos, LISPE has maintained a strong research program involving 15 Ph.D. students, 2-3 postdoctoral research associates, 2-3 visiting engineers and several visiting academics. The LISPE-Industry Research Consortium on "Artificial Intelligence in Process Engineering" has included in the last three years 20-25 companies from the oil, chemical, pharmaceutical, engineering and construction, computer and automation industries. These industrial sponsors have supported the LISPE research activities over the last three years and have been the principal conduits for technology transfer from MIT to the industry.

Presently, LISPE is maintaining a high profile among the research groups in process engineering, world-wide, and is exploring the use of artificial intelligence and other aspects from computer science in solving various problems of the processing industries such as: (a) Product design; (b) Conceptual design of new chemical or biochemical processes; (c) Analysis, diagnosis, and planning of process operations; and (d) Design and deployment of intelligent controllers. Several software systems in the above areas have already been developed and tested by industry.

Polymers

Professor Robert E. Cohen of the Chemical Engineering Department and Professor Richard R. Schrock of Chemistry have produced very small particles of lead and tin sulfide via H₂S-treatment of block copolymer films wherein the metal sulfide aggregates reside as spherical microdomains distributed throughout a rubbery polynorbornene matrix. The block copolymers were prepared by sequential ring opening metathesis polymerizations of norbornene and specially prepared metal-containing monomers. The interdomain spacings (320–480 Å) before and after H₂S treatment were revealed by small angle X-ray scattering (SAXS). Average cluster diameters (20–40 Å) were determined by transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM). The clusters were characterized using X-ray fluorescence analysis performed on the STEM and by wide angle X-ray powder diffraction.

Nanoscale semiconductor particles are of great interest for their potential use in applications such as optical switching which require nonlinear optical properties. Lead sulfide, a black solid which absorbs all visible light, absorbs in the visible region when the size of the PbS is reduced to the range of a few tens of Angstroms. Thus the new polymeric films containing the "quantum dots" of PbS are red, yellow, or orange. If the particle size distribution can be narrowed by improvements of the preparation method, there is potential for optical switching devices because the sharp absorption edge of such materials may shift with the intensity of the incoming light. Our method can also be applied directly to the production of "quantum lines" and "quantum planes" of semiconductors using the well known cylindrical and lamellar morphologies of block copolymers as precursors. Thus we have a general method which allows for one-, two-, or three-dimensional confinement of semiconductor particle size.

Chemical Vapor Deposition

The deposition of thin films by chemical vapor deposition (CVD) is a key element in a wide range of important technological processes including the fabrication of microelectronic circuits, optical and magnetic recording media, optical devices, and high performance tools. The complex gas-phase and surface reactions, combined with transport phenomena underlying CVD, must be understood in order to produce films with controllable properties; e.g., composition, impurity levels, thickness, crystalline structure, and surface morphology. Quantitative finite element models have been developed by Professor Jensen and his research group for simulating growth rate and composition as well as impurity incorporation. These models quantitatively predict growth rate and doping level performance of reactors for metalorganic vapor phase epitaxy (MOVPE) of III-V compound semiconductors. This special form of CVD is critical for the manufacture of electro-optic devices such as solid state lasers. In particular, the modelling studies have provided significant new insight into three-dimensional mixed convection flow phenomena and the relative role of gas-phase and surface reactions in MOVPE of GaAs. The work demonstrates for the first time that not only growth rates, but also electronic properties may be predicted by combining chemical kinetics with accurate transport descriptions.

Concurrently with the process modelling effort, a laboratory for studying CVD and MOVPE chemistry has been established. This facility includes systems for growth of high purity materials, mass spectroscopy and Fourier transform infrared spectroscopy (FTIR) for studying gas-phase and surface reaction mechanisms, laser direct-write equipment for deposition of spatially defined metal lines, and plasma processing systems for modification of polymer surfaces. The organometallic chemistry underlying the growth of compound semiconductors has been studied with particular emphasis on reactions of organometallic arsenic sources, including phenyl- and tertiarybutyl-arsine, which are potential replacements for the highly toxic arsine used in existing processes. In addition, growth conditions for high quality ZnSe, a material with potential applications for solid state blue light emitting devices, has been established by a comparative study of organoselenium sources and hydrogen selenide. This study also provides new insight into the relationship between the structure and reactivity of a source compound and the final materials properties of the deposited film. A new in-situ technique for generating hydrogen selenide, which avoids storing the toxic compound, has also been developed.

FACULTY

Professor Robert C. Armstrong chaired an Office of Naval Research task force charged with assessing research needs for propellant processing over the next 20 years. In addition, he gave the joint University of Michigan/Michigan State University AIChE Lecture this past fall and chaired the session on Viscoelastic Fluid Mechanics at the AIChE meeting in San Francisco in November of 1989.

Professor János M. Beér was elected a foreign member of the Finnish Academy of Technology in 1989, and he took part in the evaluation of university energy research in Sweden at the invitation of the Swedish Government. In addition, he was invited lecturer at the European Natural Gas Research Conference in Trondheim, Norway, and has been invited to be a Distinguished IBM Visiting Professor at Northeastern University in 1990.

Professor Daniel Blankschtein will be promoted to Associate Professor as of July 1, 1990. He continues to hold the Texaco-Mangelsdorf Career Development Professorship.

Professor Howard Brenner was elected a member of the newly formed International Advisory Committee, The Caribbean Congress of Fluid Dynamics. In addition, he 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 the Ernest Thiele Lecturer at the University of Notre Dame in 1989 and was appointed to the Visiting Committee for the Department of Chemical Engineering at the University of Texas in 1989. In 1990, Professor Brown became a member of the Space Science Board of the National Research Council and Associate Editor for the *Journal of Scientific Computing*. He will be 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.

Professor Robert E. Cohen became Associate Chairman of the MIT Faculty on July 1, 1989. During 1989 he was on sabbatical leave, spending the year in residence at the Department of Chemistry at Harvard University in the laboratory of Professor George Whitesides. Professor Cohen serves as chairman of the Scientific Advisory Board of the William and Mary Greve Foundation in New York City; in this capacity he has developed and implemented in 1989 a continuing fellowship program which brings young polymer scientists and engineers from Eastern Europe to the United States for a year in residence at an academic polymer research group. In 1989, Professor Cohen was named to the Editorial Advisory Board of the *Journal of Applied Polymer Science*. He presented the lead-off invited lecture in the symposium on Structure and Mobility in Solid Polymers at the Annual AIChE meeting in San Francisco in November 1989. Professor Cohen is holder of the Bayer Professorship in Chemical Engineering.

Professor Clark K. Colton served as Chairman of the NSF-sponsored Symposium on Mass Transfer in Biological Systems in Buenos Aires, Argentina, October 1989. He was Chairman of the Engineering Foundation Conference on Recovery of Biological Products V in St. Petersburg Beach, Florida, May 1990. He 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. He is an editor of the volume from the Centennial Symposium of Chemical Engineering Education which is to be published in the Advances in Chemical Engineering series in 1990.

Professor Charles L. Cooney gave the plenary lecture and was conference vice-chairman at the Second International Biotechnology Conference for the Asia Pacific Region held in Seoul, Korea in May 6-9, 1990, and was an invited lecturer for the 70th anniversary meeting of l'Association Française des Femmes Diplomees des Universites in Paris, March 8-9, 1990. Professor Cooney was also elected to the Board of the Astra Research Center in Bangalore, India.

Professor Jeffrey L. Feerer relocated to Cambridge and became the Associate Cambridge Director of the Practice School after serving almost three years as a Practice School Station Director.

Professor Karen K. Gleason received both the National Science Foundation's Presidential Young Investigator and the Office of Naval Research's Young Investigator awards.

Professor T. Alan Hatton was appointed Director of the David H. Koch School of Chemical Engineering Practice this year and will be promoted to full professor as of July 1, 1990. He was the invited keynote speaker at the Engineering Foundation Conference on Reaction Engineering in Santa Barbara and will be 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 will serve as chairman of the Gordon Conference on Separation and Purification.

Professor Klavs F. Jensen joined the Department of Chemical Engineering with a joint appointment in the Department of Materials Science and Engineering. He 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 Mark A. Kramer presented a keynote lecture at the IChE Expert Systems in the Process Industries conference in London, England. He was awarded a best paper presentation award at the 1990 American Control Conference.

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 three-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. He was also awarded the Kenneth J. Germeshausen Professorship this past year.

Professor Edward W. Merrill gave the plenary lecture, "Biomaterials," before the Materials Science and Engineering Division of AIChE at the annual meeting in November of 1989; in December of 1989 he gave an invited lecture on phase transformations of polyethylene oxide networks in a session on Chain Dynamics at Polymer Surfaces at the International Chemical Congress of Pacific Basin Societies in Honolulu; and in April 1990 he presented a paper on radiation cross-linking of polyethylene oxide at a meeting of the Polymer Processing Society (International) in Nice, France. At the ACS National Meeting in Boston, April 1990, Professor Merrill presented an invited lecture to the Polymer Materials Science and Engineering Division, and presented an invited paper on polyethylene oxide star molecules in the Symposium honoring Professor Robert S. Langer. Finally, at the Society for Biomaterials Annual Meeting in Charleston, South Carolina, May 1990, Professor Merrill received the Clemson Award for Outstanding Contributions to Biomaterials Literature and gave the plenary address entitled "Polyethylene Oxide Revisited."

Professor Charles N. Satterfield has completed the second edition of his book *Heterogeneous Catalysis in Practice* and the manuscript will enter production at McGraw-Hill in July of 1990. Publication is expected in the spring or summer of 1991, at which time it will be featured in the McGraw-Hill book club. Professor Satterfield was also appointed to the Editorial Advisory Board of the journal *Energy & Fuels*.

Professor Kenneth A. Smith was named the Edwin R. Gilliland Professor of Chemical Engineering on July 1, 1989. In addition, he continues to serve the Institute as Associate Provost, Vice President for Research, and Director of the Whitaker College of Health Science and Technology.

Professor Gregory Stephanopoulos was elected 2nd Vice Chairman of the FPBE Division of AIChE; he will chair the Division in 1991-92. In March 1990 he delivered a plenary lecture at the 2nd International Symposium in Biochemical Engineering in Stuttgart, FRG, and will be a Merck lecturer at the University of Puerto Rico in the winter. Dr. Stephanopoulos was appointed to the chair of the next International Symposium of Computer Applications to Fermentation Technology.

Professor Jefferson W. Tester was appointed Director of MIT's Energy Laboratory in July of 1989 and was selected as the outstanding professor for teaching in Chemical Engineering by the Graduate Student Council. He participated in the evaluation and formulation of renewable energy research and development issues for the USDOE as part of the National Energy Strategy initiative. In addition, Professor Tester was the chairman of a major international conference on Energy and the Environment in the 21st Century held at MIT in March of 1990.

Professor Daniel I.C. Wang delivered the plenary lectures at the Japan Society of Biosciences, Biotechnology, and Agrochemistry, in Fukuoka, Japan; the Asian-Pacific Biochemical Engineering Conference in Kungju, Korea; and Biotech '90 in Hannover, West Germany in 1990. Professor Wang was the Eminent Scholar at the University of Maryland, Baltimore County (1990) and the Sherman Fairchild Scholar (1990) at the California Institute of Technology. He was also invited to join the National Biotechnology Policy Board of the NIH for 1990-1993. Lastly, 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 was appointed chairman of a faculty committee on Global Environment to define an inter-disciplinary research program for MIT. He was the keynote speaker at the 40th Anniversary of the Chemical Engineering Department at the University of Florida at Gainesville.

AWARDS

The following awards were given at the Chemical Engineering Department Awards Program on Wednesday, May 2, 1990:

Dow Chemical Outstanding Junior Award, given to **Joseph Berghammer**, recognizes a junior in chemical engineering who has had a balanced record of achievement in academics, campus professional and social organizations, and work experience. The AIChE Scholarship which was established in 1989, is a \$1,000 scholarship given to a student based on their academic record, participation in AIChE activities, other civic and professional activities, and future career plans and was awarded to **Eleanor Meyer**. **Joseph Berghammer** was also awarded the AIChE Chapter Award for Scholastic Achievement, given to the member of the Department's AIChE student chapter with the highest scholastic performance through the first two years in Chemical Engineering. **Alisa Mosler** and **Kimberly Mislick** were awarded Texaco Philanthropic Foundation Scholarships which recognize excellence in academic performance by students who are US citizens and who have completed their junior year in Chemical Engineering. The Robert T. Haslam Cup was awarded to **Christine M. Gundal**; this award recognizes outstanding professional promise in Chemical Engineering. **Sherrill L. Briese** was awarded the Roger De Friez Hunneman Prize; the oldest prize in the Department, this is awarded to a senior for outstanding scholarship in class and research.

Initiates into Tau Beta Pi, the Engineering Honorary Fraternity, for 1989-90 were **Timothy Alosi**, **Kimberly Mislick**, **Alisa Mosler**, **Paul Ouellet**, and **Bernhardt Trout**. Chemical Engineering Department Special Service Awards were given to **Ellen M. O'Connell** for her work as President of Student Chapter of AIChE; **Aparna Bhave** for her work as President of Graduate Student Council; and **Paul Coates** and **Paul Northey** for their work coordinating departmental athletics. The Dow Teaching Prize recognizes excellence in teaching by doctoral students committed to careers in teaching and was awarded to **Richard Shandross**. The Department's Outstanding Employee Award was given to **Arline Benford** for exemplary service to the Department and its students. **Jefferson W. Tester** received both the Department's Outstanding Faculty Award, voted by Department graduate students, and the Institute's Graduate Student Council Teaching Award for Chemical Engineering. The Rock Award, a Departmental athletics award, was given to **W. Gabe Worley**.

ROBERT A. BROWN

Department of Civil Engineering

INTRODUCTION

For over 130 years, the Department of Civil Engineering at MIT has taken a vital leadership role in education and research for its profession and for the Institute. Civil Engineering is the profession most aptly called "society's engineers". Working closely with the public we focus on construction, infrastructure facilities, and environmental protection; as well as, the management of the built environment and natural resources, and protection from natural and man-made disasters. We work to provide and maintain the facilities that fuel development and economic expansion; and, at the same time protect society from potential health, environmental, and safety impacts of that development. The problems faced in this area are of even greater importance for today and for the future. The Department has worked hard and invested heavily in new research and educational programs to anticipate problem solving in hazardous waste management, infrastructure renewal, rehabilitation and management, logistics and congestion management in transportation systems, computer-based methods for improving engineering design and construction, environmental clean up, hydrologic portions of the global environment, new advanced materials, technology, and methods for increased productivity, reliability, and safety in constructed facilities. These concerns have heavy technologic components and also have major societal impacts and implications. We therefore must learn how to hear society's often conflicting needs, consider their multidisciplinary nature, and translate them into a range of sound technological solutions. Our educational programs are attracting increasing numbers of students and are models for others across the country and throughout the world. Our research programs are robust, very well funded, and taking a major leadership position for our profession world wide. This is an exciting time for us and we have risen to the challenge. Specific activities of the Department during AY 1989-90 follow:

Undergraduate Education

Environmental Engineering Science

The Department first developed a new experimental curriculum in Environmental Engineering Science at the undergraduate level four years ago. Its aim is to provide a sound and fundamental understanding of physical, chemical, biological, economic, and policy aspects of the field of environmental engineering. This program builds on the Department's strengths in fluid mechanics, environmental chemistry and biology, ecology and hydrology, and treatment technology and water resource systems. In addition, it allows a student, with faculty guidance, to build programs over an interdisciplinary spectrum; drawing on Chemical and Mechanical Engineering (sources and controls), Toxicology (human health effects), Urban Studies, Economics and Management (policy aspects). The program now has many graduate students and, although undesignated, attracts 20 plus students per year. Because of the success of the program, and the interdisciplinary cooperation we have received from other departments, we asked the Institute faculty during Spring 1990 to make this a Designated Degree Program, Course IB, Environmental Engineering Science, under Civil Engineering. This motion was passed by the Faculty and the Corporation. An important part of the program will be the formation of an interdisciplinary steering committee to consider the content of the program. It is vitally important that all Institute students, not just majors in this area, have access to subjects to build environmental literacy, and we will use this forum to help develop new subjects for the program and for all Institute students.

Engineering Systems and Computation

The Department also runs an undesignated program in Engineering Systems and Computation that stresses the engineering use of advanced information technologies. This program, now in its third year, has also attracted considerable student interest and help from across the Institute. Our Introductory Computer Course 1.00, offered as a service to the Institute, now attracts over 500 students per year. New initiatives in better integrating design into our curriculum continue.

Graduate Programs

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. In addition, 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, launched two major research initiatives. The first concerns Condition Assessment of existing facilities and the second involves the development of High Performance Design. CFD's research on Condition Assessment includes in-situ testing, image processing, and system identification. Professors Eduardo Kausel and Daniele Veneziano developed new and improved analysis procedures for interpreting radar signals in constructed facilities; Professor Oral Buyukozturk is examining the use of microwave techniques for detecting bridge repair corrosion, and Professors Veneziano and Jerome Connor are evaluating strategies for identifying structural damage due to earthquakes. In the area of high-performance design, a number of new research efforts have been initiated. Professors Charles C. Ladd and Andrew Whittle are involved with a site characterization problem associated with the Central Artery reconstruction. Professors Herbert Einstein and Robert Whitman are continuing research on novel underground construction techniques; in particular, top-down construction and new tunneling methods. Professor Lorna Gibson is examining the use of advance materials such as cellular composites to develop new types of structural components. Professor Thanasis Taintafillou is initiating a research effort directed at the use of fiber-reinforced composites as strengthening elements for both existing and new structural components. In addition to the use of advanced materials, there is on-going research concerned with the development of new concepts for structures. Novel designs for tall buildings and deployable structures are currently being researched.

In addition to the research thrust, both the undergraduate and graduate academic programs have been modified significantly. We have placed more emphasis on design at the undergraduate level, and new graduate subjects dealing with condition assessment and innovative structural systems will be improved in the near future. During the upcoming year CFD plans to integrate these two research themes and provide an environment that would foster interaction between staff members of the Constructed Facilities Division and staff members from other departments.

Transportation Systems Division (TSD)

Activity in TSD has focused on three areas: congestion, infrastructure, and logistics. Progress in these three areas is reviewed as follows. Congestion: 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 (Professors Koutsopoulos, Ben-Akiva, Bernstein and others) 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. Infrastructure: Professors Livneh (Technion) and Talvitie (Finland DOT) have been visiting in CFD this year. Professor Livneh is an expert in the mechanics of pavement, and Professor Talvitie is an expert in infrastructure management. They have offered a course on infrastructure and worked with Professor Fred Moavenzadeh and Moshe Ben-Akiva. Logistics: 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. The major activity this year has been the establishment of a joint CTS/Sloan program where MS students will be registered one year at Sloan and a second year in Civil Engineering. These students will work towards a 24-month, two degree program involving summer internship and an engineering-school style thesis. The first students are expected to start the program in September 1990.

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 will have the management responsibilities for, the new undergraduate designated program in Environmental Engineering Science. In particular, they will be working with other departments within the Institute to enhance the subject offerings and content not only for this major but also to provide access to environmental literacy for all students at the Institute. The group continues to have a strong individual research base involving more than \$4 million/year in funding and is continuing to build in several collaborative investigation areas. One is the continued effort to identify the actual chemicals causing human health problems in an urban environment, such as the Aberjona River Watershed (Woburn, MA and surroundings). During the year, Professor William Thilly, of the Toxicology Group in Whitaker College, received a secondary appointment within the Department and is greatly adding to our activities in this area. The biologically-directed exposure assessment being pursued is an exciting new approach likely to revolutionize how hazards derived from toxic wastes in our environment are evaluated. Coordination of work with the Center for Environmental Health Sciences, and the Hazardous Substances Management Program, has led to increased synergy with other groups within the Institute. Another major focus has involved issues of waste disposal in and around Boston Harbor. This has led to an investigation of the fate of particles introduced into this system via combined sewer overflows and the recycling of the system from one depositional site to another. Research also focuses on the identification of the critical processes and controlling factors enabling the release of toxic chemicals from such deposited particles back into the overlying ecosystems. Both numerical and physical modelling studies have been performed to optimize the siting of the planned ocean sewage outfall and efforts are getting underway to test the effectiveness of chemical coagulants for treating Boston area sewage.

A major segment of the group has become heavily involved with issues of Global Climate Change. Several faculty members described work related to this in the Institute's seminar series on this topic. Professor Rafael Bras has begun his appointment as Associate Director of the newly organized Center of Global Change Science. Research involving remote sensing of physical and biological properties of both land and sea states has also been actively pursued providing critical observational inputs to the huge modelling efforts in this area.

Center for Construction Research and Education (CCRE)

In the eight years since its formation, the Center for Construction Research and Education 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, remote sensing, construction finance, management of technology, and strategic management. Many are already being placed at top universities and in industry. The Center also continues to be successful in developing large-scale umbrella research programs. The Army-sponsored five-year Program for Advanced Construction Technology (PACT) is now in its fourth year. The

PACT program focuses on basic research and fellowship support in the area of construction engineering and technology. During the first three years (1987-89), PACT funded 48 research projects, 19 fellowships, 30 research assistantships and purchased \$1.4 million of research equipment and instrumentation. The research projects have involved 23 faculty and research staff members: 18 from Civil Engineering, 2 from Management, and one each from Mechanical Engineering, the Media Lab, and Material Science and Engineering. 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 and infrastructure assessment; advanced engineered materials (composites, ceramics and polymers); integration of design and construction; and infrastructure maintenance management.

Accomplishments in the area of industry interactions this past academic year included: the presentation of a subject "Geo-Construction: The Geotechnical and Environmental Aspects of Foundation and Earthwork Construction" by the firm of Haley and Aldrich, Cambridge, MA; the presentation of another subject "Project Execution in the Industrial Sector" by Jack Kavanagh, President of Badger America, Inc., and the continued involvement of six other industry experts and outside academic specialists in the teaching of CCRE subjects.

The Center is currently ideally positioned to take maximum advantage of a number of trends including: the construction industry's growing recognition of the importance of R&D and its interest in working jointly with academic institutions, the sustained interest of the Army Corps of Engineers in construction research, and the increasing number of construction engineering and management programs at other universities throughout the nation.

The Intelligent Engineering Systems Laboratory (IESL)

This is a group of faculty, students, staff, and industrial-funded visiting engineers devoted to exploring the applications of computing and communications technologies in engineering. Funded by an industrial consortium at the level of \$1.5 million/year, IESL has undertaken research projects in concurrent engineering, visualization of complex structures through the use of multimedia, real-time control of air traffic systems, and the use of massively parallel computers in network analysis. These projects share the extensive computational resources of the lab.

During the year IESL initiated a doctoral program in computer aided engineering. In addition, it maintains responsibility for the Department's Engineering Systems and Computation undergraduate program. Activities of IESL involve 5 of the Department's faculty, 13 graduate research assistants, 6 visiting engineers and a number of UROP students. New initiatives of IESL include a joint project proposal with the Visual Computing Group of Project Athena to extend the usefulness of multimedia presentation systems.

Department Administration

Department Head, Professor David H. Marks
Chairman of the Undergraduate Program, Professor Keith Stolzenbach
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 Charles C Ladd
Coordinator of the Student Chapter of ASCE, Professor Lorna Gibson
Coordinator, Chi-Epsilon, Civil Engineering Honorary Dr. Jack Germaine
Head (Acting), Water Resources and Environmental Engineering Division, Professor Philip Gschwend
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

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 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 Phillip 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 Thanasis Triantafillou joined the faculty in January 1990 in the Constructed Facilities Division, Assistant Professor David Bernstein joined the faculty in April 1990 in the Transportation Systems Division. Three faculty resignations were received: Professor S. Shyam Sunder, Professor Victor Li and Professor Alex Slocum. Two faculty were on leave: Professor Rafael Bras, and Professor Alex Slocum.

Departmental Statistics

Number of Faculty: 38, June 1990. Number of Undergraduates: 114; this is up from 72 in 1987 (an increase of 58 percent). Number of graduate students: 247. Department research expenditures for AY 89-90: \$7.5 (up from \$6.8 last year).

Faculty and Staff

Dr. E. Eric Adams, Principal Research Engineer (WREED), continues his research on Boston Harbor, completing a physical model study of seawater intrusion and purging for the proposed ocean outfall at Boston's new sewage treatment plant. He is also conducting a fluorescent tracer field experiment designed to better understand initial deposition of sewage particles. He is organizing an International Conference on Physical Modeling of Transport and Dispersion to be held at MIT this August, and is Chairman of ASCE's Hydraulics Division Awards Committee.

Professor David Bernstein (TSD) joined our faculty in April 1990 after completing his Ph.D at the University of Pennsylvania. He is currently conducting research in the areas of transportation demand management (including on-street and on-site parking policies and driver incentive programs); transportation and land use interrelationships; network equilibrium models; and computer systems in transportation

Professor Rafael Bras (WREED) has been active in publications. The year started with the publication of Hydrology: An Introduction to Hydrologic Science (Addison-Wesley). In addition, two edited volumes of material presented in conferences that he hosted last year were completed. One volume was published by the National Research Council of Italy and NSF, and the other as a special issue of the Journal of Geophysical Research - Atmospheres of the American Geophysical Union. Another big project was the creation of a twenty-minute computer animation of River Basins Evolution, a project he had been planning for a year. He has been a member of the NSF Engineering Directorate Advisory Committee, of the Board of Atmospheric Sciences and Climate (NRC-NAS), and has been appointed to the Advisory Committee of NASA's Earth Sciences and Applications Division. Although on sabbatical leave, he has been involved in two major initiatives at MIT. One is as Associate Director of the Center for Global Change Science and the other is the new Undergraduate Degree in Environmental Engineering Science.

Professor Oral Buyukozturk (CFD) developed, and offered during Spring 1990, a graduate advanced design course 1.544, in conjunction with the Architectural Department's Building Systems Workshop 4.52. The objective was to have the architectural and structural students interface through an innovative design project, and to simulate the architect/engineer interaction in the real world. The course provided an opportunity for the students and the faculty from the Civil and Architectural Departments, and from the Harvard School of Design, to work closely together throughout the semester. In conjunction with the course, he has also organized the second Abraham Woolf Lecture Series on design. He has joined the US-Japan Scientific Committee on Finite Element Analysis of Concrete Systems to develop a workshop which is expected to be sponsored by NSF and the Japanese government.

Professor Sallie W. Chisholm (WREED) is Chair of the Joint MIT/Woods Hole Oceanographic Program this year. She was elected a Council Member of the Oceanography Society and was appointed to the Steering Committee of the US Global Ocean Flux Study. She was also an invited lecturer on the "Environment in the 21st Century" at a Symposium on War and Peace at the State House.

Professor Jerome J. Connor (CFD) is conducting research in the following areas: computer-aided engineering design with emphasis on the development of a rational basis for reasoning about constructability during the design process, a virtual environment which integrates computer graphics and video technologies and allows one to process multimedia presentations in real time, and innovative structural design concepts for buildings. He Co-chaired the US-Japan Conference on Boundary Element Methods held at Stanford University, and will be attending the follow-up conference in Japan next Fall. In addition, he has been invited to deliver a keynote lecture at the 2nd International Conference on Computer Methods and Water Resources in Moscow next Spring. He is currently involved with a new research initiative in visual computing and the preparation of a monograph on "Design Innovations for Constructed Facilities."

Professor Richard de Neufville, Director of the Technology and Policy Program (TPP), continues to help build, evolve, and lead MIT's efforts in technology and policy education. The program presently has about 60 students in its professional SM degree and several Ph.D students. He will be giving two summer courses in Airport Systems Planning and Water Resource Systems.

Professor Peter Eagleson has continued his leadership of varied efforts to create a national infrastructure for hydrologic science. The long term objective is to build the research and educational base necessary to forecast and cope with water-related environmental change over a wide range of space and time scales. He was named a Fellow of the AAAS.

Professor Herbert Einstein's (CFD) work in the Project Athena course ware includes the conversion of the GROWLTIGER structural engineering educational program to better fit an electronic classroom set-up. He also participated in the School's new major engineering and science education coalition proposal. A major emphasis of this proposal is on design and two major efforts have been adopted by practice. The landslide risk analysis is part of the Himalayan-Hindukush Mountain Risk Engineering Manual. The Swiss government is going to use the tunnel simulator for their new 50 kilometer Tansalpine tunnel after more research and development at MIT.

Professor Lynn Gelhar (WREED) is completing a textbook entitled "Stochastic Subsurface Hydrology" which is scheduled for release in 1991. His research, focusing on field-scale contaminant transport in groundwater, includes cooperative large-scale field investigations in the New Mexico desert, in northern Mississippi, on Cape Cod, and in the Aberjona River watershed just north of Boston. On the Aberjona site, which encompasses the highly publicized contaminated water supply wells in Woburn Mass., he is cooperating with Professor Hemond to develop a computer-based model which simulates the groundwater flow over the entire watershed. He has also initiated theoretical work on biodegradation of contaminants in groundwater which is elucidating previously unrecognized field-scale effects.

Dr. John Germaine (CFD) has remained heavily involved with the American Society for Testing of Materials (ASTM), and developed the concrete canoe project into an Institute

undergraduate subjects. The automated triaxial equipment has become the central device for two research projects and will be heavily used in a third. This advanced technology is making it possible to perform the detailed experiments necessary to investigate material behavior. Current projects are performing experiments to identify the mechanism controlling the mechanical properties of frozen soil and strain rate sensitivity of clay. He was the recipient of the 1990 Hogentogler Award (with Prof. Ladd) of ASTM for best paper published in geotechnical engineering.

Professor Lorna Gibson (CFD) was granted tenure this year for her educational and research contributions (particularly in the field of the mechanical behavior of materials with a cellular structure). She plans to take a sabbatical next year at Harvard collaborating with the applied mechanics group on composite cellular materials and with the orthopaedic biomechanics group on the failure of cancellous bone. She will be continuing her projects on improving core materials for structural sandwich panels and on cementitious foams. She will also be initiating a new project, funded by the Department of Energy, on Microstructural Design in Cellular Solids.

Professor Philip Gschwend (WREED) has made several advances documenting the importance of colloids for controlling the transport of organic pollutants. For example, in addition to recent data showing substantial colloidal loads in contaminated groundwater, he now has evidence that these microparticles and macromolecules may carry low-solubility pollutants present. While continuing efforts to understand the controls on colloid presence, he is now working with the US DOE, the NJ DEP, and New York State Electric and Gas Corporation to assess colloidal phenomena of waste sites of interest to them. In a second major effort, he is showing that colloids may greatly enhance the return of toxic chemical from sediment beds to overlying waters and biota. Using Boston Harbor cores, together with modelling calculations, he finds that pollutants in the sediment porewater are colloid-bound and that bioirrigation probably flushes this contaminant load out. Thus unhealthy fluxes may be anticipated for decades to come. This NSF-, Sea Grant- and MWRA-supported research strongly suggests the need to clean up such polluted beds.

Professor Donald R. F. Harleman (WREED) has increased his involvement in the Boston Harbor cleanup technology/policy conflict. Boston is now embarking on a 10 year, \$6 billion construction period utilizing outmoded waste treatment technology mandated by the 1972 Clean Water Act. Beginning about ten years ago, new and simpler waste treatment processes involving the use of ferric chloride and polymers to increase pollutant removal by coagulation and flocculation have been developed particularly in Scandinavia. His efforts have been directed to the adoption of this new technology in Boston and in other coastal urban areas. The billions of dollars saved in capital costs would permit remediation of the most serious pollution problems caused by frequent storm water overflows. Resistance to technology innovation comes from State and Federal regulatory agencies as well as from the consulting engineering profession. At his request, a National Research Council committee on Waste Management in Urban Coastal Areas has been formed to deal with the problem.

Professor Harold Hemond (WREED) continues research and teaching in the environmental area with a strong field level influence. He successfully tested, under manual control, a self-contained portable mass spectrometer for field use. He continued research on a membrane probe tip of adequate mechanical ruggedness and made major improvements to mass spectrometer inlet system. Research on hydrology, chemistry, and industrial history of the Aberjona watershed also continues. He documented widespread migration of chromium, arsenic, and other inorganic contaminants. He identified the impact of a groundwater plume, based in Stoneham, on surface water analysis and has found mutagenic activity in Aberjona River sediments. He is now proceeding with human cell assay. He continued research on trace gas emissions from ecosystems, focusing on mechanics of methane ebullition from northern bogs (believed to be a major player in the global methane budget). In acid deposition research he developed a model which represents natural organic acidity in a conceptually correct fashion, while identifying a conceptual problem in the almost universally used measure of ANC (Acid Neutralizing Capacity) as used by NAPAP and most contemporary workers.

Professor Eduardo Kausel (CFD) continues his evolution into the areas of structural acoustics and into condition assessment of structures. He is an Associate Editor of the

Journal of Engineering Mechanics and participated in the NSF ASCE Workshop on Research Priorities in Engineering Mechanics at the Structures Congress in Baltimore, Maryland. He presented an invited seminar at the Technical University of Berlin.

Professor Haris Koutsopoulos was co-recipient of the Department of Civil Engineering's Most Effective Teaching Award for 1989 for his teaching of the undergraduate course "Introduction to Computers and Engineering Problem Solving" which had an enrollment of approximately 300 students (Spring 1989). He was also recipient of the The Winslow Career Development Chair. He was appointed member of the TRB Committee on Emerging Technologies and the Transportation Supply Committee.

Professor Charles C. Ladd (CFD) started a new research project with Haley & Aldrich, Inc. to perform specialized consolidation and strength testing on tube and block samples of Boston Blue Clay in connection with geotechnical design of earth retaining structures for the Boston Central Artery/Third Tunnel project. He was the recipient (with Dr. Germaine) of the 1990 Hogentogler Award of ASTM for best paper published in geotechnical engineering. He was appointed to a six-year term on the Executive Committee of Geotechnical Engineering Division of ASCE.

Professor Steven Lerman (TSD) is the Director of the Civil Engineering Department's Intelligent Engineering Systems Laboratory (IESL). IESL has a budget of \$1.5 million/year and is devoted to new innovations in computer aided engineering and design. His research has focused on the development of network algorithms for massively parallel computers. The long term goal of this research is to improve the computational performance of traffic assignment, traffic signal timing, and routing algorithms to the point where real time operational control of urban transportation systems is both computationally feasible and economically practical.

Professor Robert Logcher (CFD) and Professor Sriram organized a joint US/Japan Workshop on Cooperative Product Development which was attended by 60 US and Japanese researchers and practitioners in November. He gave a keynote presentation on the Use of Object Oriented Systems for Management of the Design Process at the CIB W55/W65 Congress in Sydney, Australia in March. He started a new project on the use of real time AI for flow management in the air traffic control system. He was awarded a new grant by NSF for further research on deployable structures.

Professor Ole S. Madsen (WREED) participated as the only "engineer" in the Benthic Boundary Layer Group of the NSF-sponsored Coastal Physical Oceanography Program (CoPo) and initiated a joint research program on this topic with scientists at Virginia Institute of Marine Science (VIMS), combining the strength in theoretical modeling ability at MIT with the field experimental capability available at VIMS. He received, for the second time, the Graduate Student Council's Departmental Teaching Award. During IAP he participated in the freshman admission process by reading a total of 65 folders.

Mr. Carl Martland, Principal Research Associate (TSD) was the Co-Chair and the Editor of the Proceedings for a conference on "Meeting the Challenge of EDI: A Perspective on the Broader Issues Facing Carriers, Shippers, and Suppliers" which was sponsored by the Transportation Research Forum. His paper (with Michael Smith of Burlington Northern Railroad) won the Conrail Award for the best rail paper presented at the Transportation Research Forum's Annual Meeting. He initiated a new research project to help the railroad industry evaluate the economic impacts of heavy axle loads, and continued research for the Association of American Railroads and for Burlington Northern Railroad aimed at the development of better tools for track maintenance planning.

Professor Dennis McLaughlin (WREED) started a major new field project in the area of groundwater contamination. He is involved in multilevel sampling for measuring subsurface contaminant migration at a coal tar disposal site in upstate New York. Data collected from this field investigation are being used to update model-based predictions of contaminant migration. The field project and related simulation work are being funded by the electric utility industry. He continues in his work for the US Nuclear Regulatory Commission in its efforts to develop scientifically-based methods for licensing low-level radioactive waste disposal sites. He began an innovative curriculum development project involving the cooperation of Professor Adel Sarofim of

the Department of Chemical Engineering and Dr. John Ehrenfeld of the Center for Technology Policy and Industrial Development. The goal is to provide a realistic groundwater remediation design exercise which can be used in classes in both Chemical and Civil Engineering.

Professor Chiang C. Mei (WREED) continues research in the following areas of engineering mechanics: 1) Nonlinear dynamics of ocean surface waves in the presence of wind. Results show that wind can contribute to the downshift of peak frequency of the wind wave spectrum, 2) Nonlinear interaction of short and long ocean waves by the Lagrangian description, 3) Dynamics of highly concentrated fluid mud which can be cohesive sediments on the sea bottom, debris in rivers or lava from volcano eruption. A non-Newtonian theory has been established to predict roll waves, 4) Chaotic vibration of bubbles in water. It is found that simple harmonic ambient sound can induce chaotic vibration and radiation of random sound. This is of interest in the interpretation of acoustic sensing of breaking waves, and soil consolidation of large deformation. Efforts are now directed to include soil inhomogeneity of different scales and the effects of water and heat flows as in a geothermal reservoir.

Professor W. Kendall Melville (WREED) in collaboration with Prof. Kong of MIT's Electrical Engineering and Computer Science Department and others mounted a long term remote sensing experiment from a Shell production platform in the Gulf of Mexico. The results of this NASA- supported experiment will lead to improved algorithms for oceanographic applications of radar altimetry. He also participated in an ONR supported surface waves experiment (SWAPP) off the coast of California. International collaboration with the Institut de Mecanique de Grenoble on research into problems in coastal oceanography is continuing with the support of NSF and CNRS.

Professor Fred Moavenzadeh, Director, (CCRE) organized a two-day workshop (co-sponsored by the World Economic Forum) on "Engineering and Construction," held at MIT on October 17-18, 1989. The workshop was attended by over 72 construction CEOs from 26 countries. He was asked to speak at several seminars, workshops, and meetings on various construction-related topics, including the following: Construction Industry Institute's Academic Council's Annual Conference, Construction Information Executive meeting on the topic of "Importance of Information Technology to the Future of the Construction Industry," the 1989 ASCE National Convention, National Home Builders Workshop on International Development in Housing, Seminar at Oakridge National Research Laboratory on the topic of "Advanced Construction Technology," the ASCE Forum on Engineering Education, at the International Technoplis Conference, and at the Construction Futures Council Meeting. He has been chosen to be the Chairman of the Editorial Board of the newly formed Journal of Construction Business Review.

Professor Francois Morel (WREED) has taught graduate subjects in Aquatic Chemistry and Aquatic Particles. Over the past year, he has published with D. Dzombak, a former Ph.D student (now an Assistant Professor at CMU), a monograph entitled "Surface Complexation Modelling" (Wiley & Sons 1990). Highlights of his research include the demonstration of the role of cadmium as an essential algal nutrient in zinc impoverished oceanic waters and the establishment of the chemical and biochemical kinetics of iron uptake by algae. This work, which has implications to the global carbon dioxide cycle, is being continued through field studies in the Pacific Ocean. Ongoing research also includes the establishment of a biochemical marker of metal pollution and the development of a thermodynamic model of metal binding by humic substances. He also participated in national and international meetings and NRC workshops. He heads the Scientific Advisory Board for Boston Harbor and is Associate Director of MIT's Center for Environmental Health Sciences.

Professor Daniel Roos has been appointed Chairman of the Committee for the Study to Assess Advanced Vehicle and Highway Technologies. This Committee established by the Transportation Research Board, National Research Board, and National Research Council, is examining the concept of Intelligent Vehicle Highway Systems (IVHS). Through advanced electronics, computer and communications technologies we now have the ability to integrate the vehicle driver and guideway and achieve improved safety and enhanced urban mobility. The Committee is examining how a national IVHS Program should be developed and implemented.

Professor Yosef Sheffi (TSD) finished a research project with Burlington Northern Railroad (BN) on "Algorithms for Optimal Car Distribution." Burlington Northern Railroad has decided to adopt this approach and will implement the new method in the coming year. He also continued his work on using network optimization methods, in general, and information from dual variables, in particular, for pricing of intermodal services. This work is supported by BN. He also worked on truck dispatching models and, in particular, routing and scheduling using a microcomputer environment. He started a new program with the MIT Sloan School of Management in the logistics area. This is a joint Sloan/CTS masters track leading to two degrees. The first students are slated to begin in September 1990.

Professor S. Shyam-Sunder (TSD) is continuing research in the following areas: 1) nonlinear ice mechanics and ice-structure interaction with emphasis on the development of numerical models to simulate deformation and failure processes; 2) interface mechanics focussed on the molecular dynamics of ice adhesion on solids as well as the deformation and failure of adhesively-bonded joints involving flexible elastomeric membranes. He was invited to speak on his work at the Center for Building Technology, National Institute of Standards and Technology, and at a research review meeting organized by the Canada Oil and Gas Lands Administration.

Professor Duvvuru Sriram (CFD) taught a new subject entitled 1.552 Computer-aided Engineering II. This subject focused on the development of large scale software engineering products. A knowledge-based programming environment - COSMOS - was the end product. He hopes to utilize COSMOS in a Fall semester graduate course. In addition, with Prof. Chris Tong, he has been selected to give the Artificial Intelligence in Engineering Design tutorial at the American Association of Artificial Intelligence 1990 annual meeting (approximately 5,000 people attend this conference). Professor Sriram and Dr. Amar Gupta, MIT Sloan School, were awarded a grant by the Army and the Air Force for the development of a computer-based framework for technical manuals. He was also awarded a Presidential Young Investigator's Award matching grant, nearly \$45,000, from the Digital Equipment Corporation. He, along with Professor Logcher, conducted a very successful workshop on computer-aided cooperative product development. Springer Verlag has tentatively agreed to bring out the proceedings of the workshop. He was invited to become a member of the Advisory Board for the Journal of Information Science and Technology and the International Journal of Systems Automation Research and Applications.

Professor Keith Stolzenbach (WREED) completed his work as Chair of the Faculty Committee on Undergraduate Admissions and Financial Aid by presenting a report at an Institute faculty meeting in October. As Associate Director for Research for the MIT Sea Grant Program, he organized the Second Annual Workshop on Water and Sediment Quality in Massachusetts and Cape Cod Bays which was attended by 70 scientists, engineers, and environmental managers. The Sea Grant Marine Center Project on Coastal Water Quality, of which Professor Stolzenbach is the principal investigator, received a total of \$267,000 in outside funding during the current year. The Massachusetts Bays Program, for which he is Co-Chair of the Technical Advisory Committee and a member of the Management Committee, was designed by EPA as a component of the National Estuary Program. He completed his fourth year as Department Undergraduate Officer. During his tenure in this position the undergraduate enrollment of the Department doubled and the Department's proposal for a designated degree in Environmental Engineering Science was approved by the Institute's faculty.

Professor Joseph Sussman (CTS) continued in his capacity as Director of CTS. This interdepartmental Center is charged with developing and coordinating transportation research, education, and industrial outreach at the Institute. A particular initiative of the Center is development of a program in "Intelligent Vehicle Highway Systems." He participated in a number of national committees and workshops and wrote several articles to help develop these concepts.

Professor Thanasis Triantifillou (CFD) joined the faculty in Spring 1990. His primary focus is on the development of innovative design concepts via the application of advanced composites in conjunction with more conventional construction materials such as concrete, steel and wood to optimize structural performance. Specifically he is

studying the use of unidirectional polymer composite sheets in the strengthening of structures and the development of a novel technology for external post-tensioning of structural members with composite materials. He is involved in a research collaborative effort with the Swiss Federal Material Testing Institute (EMPA). His objective is a fundamental understanding of the behavior of advanced materials when combined with conventional materials and, based on that, the establishment of new concepts for the rehabilitation and/or new construction of structures.

Professor Robert Whitman (CFD) has been heavily involved in a School of Engineering Consortium proposal. He will begin to switch into an increased emphasis on educational research and teaching. This new emphasis will include development of an introductory project design subject at the freshman/sophomore level plus he is beginning to work toward a reintroduction of design throughout the undergraduate curriculum. Meanwhile, work on research for the new Post Office Square Underground Parking Garage is nearing completion. He ran a workshop as part of his project for NCER (standard reference sites for ground motion hazard mapping) and has a preliminary design for a dynamic shaker for the centrifuge. He was awarded an Honorary Doctorate of Science by Swarthmore College - his alma mater.

Professor Andrew Whittle (CFD) has developed a new graduate subject in foundation engineering which focuses on geotechnical aspects of the analysis and design for a wide range of modern foundation systems. His main research interest is in analytical methods and modeling of soil behavior as applied to geotechnical engineering problems. He is currently conducting research in the interpretation of soil properties from in-situ penetration tests using rational analytical methods for the Air Force. A second project involves a fundamental study of the mechanics of earth mass reinforcement using geosynthetic materials. Work in this project has included the design and development of experimental apparatus to measure soil reinforcement interaction. Modeling of soil behavior has also been used extensively to predict and interpret deformation around deep excavations in soft clays. This work has been developed in conjunction with construction of the Post Office Square Garage in downtown Boston. The work will shortly be used for a major subway project in Taipei.

Professor Nigel Wilson (TSD) was co-recipient of the Department's Most Effective Teaching Award for 1989 for contribution to the Department's largest undergraduate course 1.00 Introduction to Computers and Engineering Problem Solving. He was also appointed Associate Editor for Transportation Science and continues to serve on the Editorial Advisory Boards of Transportation Research and the International Union of Public Transport Revue. This year he stepped down, after six years, as Chairman of the Transportation Research Board Committee on Transit Management and Performance, but continues to serve as a member of that Committee. During the year he also served as a member of a panel reviewing the Urban Mass Transportation Administration Section 15 Program for the US Department of Transportation.

DAVID H. MARKS

Department of Electrical Engineering and Computer Science

The 1989-1990 academic year marked the first for the new department head team of Professors Penfield, Corbató, and Shapiro. The previous department head, Joel Moses, and one of the previous associate department heads, Richard Adler, stepped down as of September 1, 1989.

This year three emeritus faculty passed away, namely Y. W. Lee, an expert on statistical theory of communications, Harold E. "Doc" Edgerton, world renowned inventor and explorer, and creator of flash photography, and Joseph C. R. Licklider, eminent computer scientist and expert on man-machine interaction. In addition, we were shocked at the accidental death of Prof. Richard B. Adler in February 1990. Prof. Adler had, only a few months earlier, stepped down as associate department head, and was serving as co-director of the Microsystems Technology Laboratories. He had been expected to carry on as director of MTL through the next two academic years, until his retirement. After his death, a search was made for another director, and Prof. Rafael Reif has agreed to be the director of MTL starting September 1, 1990.

Undergraduate enrollment in the department seems to be on the rise. The best leading indicator is the number of sophomores who choose to major in electrical engineering or computer science. This number rose by about six percent according to figures for Fall 1989, and early indications are that another 10 percent rise is possible in Fall 1990. It is too early to be alarmed, of course, but it is quite possible that in future years we will be faced with a problem of coping with high enrollment similar to the problem of the early 1980s.

One of the exciting developments this year has been the thought given to reconstructing the undergraduate curricula leading to the first professional degree, both in electrical engineering and in computer science, without an *a priori* constraint limiting the length of the program to four years. Without this constraint, programs with significantly improved intellectual content can be imagined. It is possible that, if all the bugs can be worked out of our plans, our pre-professional programs can be significantly improved for classes entering MIT in the mid to late 1990s.

UNDERGRADUATE PROGRAM

Enrollment of undergraduates averaged 950 in 1989-90, with about 60 percent in the Electrical Engineering Program and 40 percent in the Computer Science Program. The apparent growth (total undergraduate students) of six percent (approximately 50 students) during 1989-90 reflects in part the inclusion of transfer students to the official count. Thus a total of 275 sophomores were enrolled in the department this year. Initial estimates indicate that a sophomore class of about 295 students will enter the department in the Fall of 1990. This is over our target of 270 students per class.

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 Brian A. LaMacchia of Rockville, MD (first prize), and to Christopher C. Bogan of Branford, CT (second prize). Honorable Mentions went to Christian D. Rheault of Medfield, MA, Penn S. Loh of Lansdale, PA, Brian S. Luschwitz of Apalachin, NY, Farzana I. Khatri of Bethesda, MD, and to Rahul Sarpeshkar of Bangalore, India.

The David Adler Memorial Thesis prizes for Undergraduate Theses in Electrical Engineering were presented to Jay N. Damask of Bellport, NY (first Prize), Peter J. Gordon of Breinigsville, PA (second prize), and Alfred Ortiz of Mayaguez, PR (third prize).

The Charles and Jennifer Johnson Prize for the outstanding undergraduate thesis in Computer Science was presented to Carl Gustave de Marcken of Babbitt, MN.

The William A. Martin Memorial Prize for the best thesis in Computer Science was won by Nathaniel D. Osgood of Chappaqua, NY.

The Undergraduate Computer Systems Prize was awarded to Ellen Spertus of Northfield, IL.

The George C. Newton Prize for the best undergraduate laboratory project was awarded to Theodore Pascaru of Great Neck, NY.

The David A. Chanen Writing Award, for the best Computer Science paper used to satisfy the second phase of the Writing Requirement, went to Brian A. LaMacchia.

Two Special Recognition Awards were presented by the Department Head to Arthur Lent of Dix Hills, NY, and to Pankaj Oberoi of Robbinsville, NJ.

GRADUATE PROGRAM

In September, 1989, there were 651 graduate students enrolled in the department. Of this number, 200 were newly admitted. About 20 percent of the total were foreign nationals. The department supported 334 Research Assistants, 97 Teaching Assistants. In addition, there were 132 fellowships including 36 National Science Foundation Fellows, seven Hertz Fellows and nine ONR Fellows. The remaining students had industrial or foreign support or were using their own funds.

During 1989, the department awarded 163 Master of Science degrees, 14 Electrical Engineers, and 63 Doctorates.

The department received 1726 applications for the 1990-91 year, a slight increase over 1989. The applications continue to be generally excellent and 290 were admitted (for February, June, and September), of whom we expect approximately 190 to register for next fall.

A number of awards were made to graduate students for excellence in teaching. Michael R. Blair of Gaffney, SC received the Carleton E. Tucker Award and Kathryn A. Millis of Lynn, MA received the Harold L. Hazen Award. Frederick C. Hennie III Awards for excellence in teaching were presented to Tracy M. Clark of Corry, PA and Hsiu C. Han of Taiwan, R.O.C. Franklyn A. Turbak of Convent Station, NJ was the recipient of the Goodwin Medal. Susan A. Hass and John S. Pezaris were promoted to Instructor G in recognition of their demonstrated teaching abilities and services to the department.

VI-A INTERNSHIP PROGRAM

In its 72nd year, the Department's VI-A Internship Program continued its popularity and excellent performance. During the annual selection process the participating companies interviewed 156 sophomore applicants (60 percent of the class) and as of June 1990, 86 student (55 percent) were selected members of the incoming VI-A class.

Company participation remained stable with no new companies added this year. However, for the first time, this class will have students participating in the newly formed Consortium For Superconducting Electronics; two will be associated with IBM and two will be with MIT Lincoln Laboratory.

In June, 46 VI-A students received their Master's and Bachelor's degrees simultaneously, having completed all of their company assignments and their Institute degree requirements. There were also 34 students who were awarded their Bachelor's degrees, most of whom will continue into the graduate phase of the Program.

At the annual Department Social & Awards ceremony at the Boston Museum of Fine Arts, the following students were honored: The Ernst A. Guillemin Award for outstanding undergraduate thesis went to Brian A. LaMacchia, who also received the David Chanen Prize for excellence in writing by a Computer Science undergraduate.

The George C. Newton Award, for the best laboratory project, went to Theodore R. Pascaru, and a Department Special Meritorious Award went to Pankaj Oberoi for his running of the highly successful 6.270 contest during IAP '90.

Receiving the Frederick C. Hennie III Award for outstanding teaching was Tracy M. Clark.

Alice A. Chang achieved the New England Championship Fencing Crown at Brown University, last February, and led the MIT women's team to a final third place finish.

MICROSYSTEMS TECHNOLOGY LABORATORIES (Professor Dimitri A. Antoniadis)

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 the following research facilities: the Integrated Circuits Laboratory (ICL), the Technology Research Laboratory (TRL), the Submicron Structures Laboratory (SSL), the Research Group Laboratories (RGL), and the Computation and Communication Network facility.

The research dollar volume in FY90 was \$4.8 million. The people involved include 12 faculty, six research staff, 121 graduate students, 32 undergraduate students, 19 technical support staff, and 10 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, 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 Center for Space Research; the Turbulence Research Laboratory; and the Harvard-MIT Division of Health Sciences and Technology. During the 1989-90 academic year, 16 PhD and 24 SM degrees were awarded in conjunction with this research.

Research in MTL may be grouped into eleven categories:

- (1) Integrated Circuits includes analog and digital integrated circuits design as well as advanced process development for "mixed analog/digital signal" IC applications.
- (2) Integrated Sensors includes technologies for micromachining, design of microsensors and microactuators, and the application of these devices to physical and chemical measurements.
- (3) Power Devices and Circuits includes several projects supporting broader research at MIT in very high frequency power converters, while other projects are directed toward power device performance and novel fabrication procedures for energy storage devices.
- (4) Electronic Devices includes devices operating in the semi-classical regime.
- (5) Quantum Effect Electronics includes 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 includes some "nanofabrication" projects that are not directly related to electronic devices. The Submicron Structures Laboratory develops techniques for fabrication surface structures which 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 to solve complex problems of carrier transport and device operation 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 applications, includes 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 thin films on amorphous substrates.

(11) Packaging includes advanced chip assembly and study of passivating properties of different materials in thin film form.

The Laboratories include three clean room facilities and an associated non-clean laboratory space. The centerpiece facility is the Integrated Circuits Laboratory, a state-of-the-art class-10 clean lab with full capabilities for modern IC fabrication. This lab is operated by both full time technical staff and graduate students. This past year it has achieved "fully qualified" status.

The facilities that enable some of this research are supported in part by the members of the MIT Microsystems Industrial Group (MIG), whose current members include: Analog Devices, Inc.; AT&T; Digital Equipment Corporation; Draper Laboratories; General Motors Corporation; IBM; NCR Corporation; Polaroid Corporation; and Raytheon Company.

Coordination activities carried out by MTL include the weekly VLSI seminar series, a unified VLSI Memo Series, and an annual Microsystems Research Review. The MTL publishes the annual report titled *Research in Microsystems Technology*.

FACULTY

After serving the department for eight years as Department Head, Professor Joel Moses stepped down to return to teaching and research. Professor Richard B. Adler, who began serving as Associate Department Head in 1978, also stepped down and became co-director of the Microsystems Technology Laboratories. We welcomed Professor Paul Penfield, Jr. as the new Department Head and Professor Jeffrey H. Shapiro as the new Associate Department Head. Professor Fernando J. Corbató continues as Associate Department Head.

This year three faculty members were promoted to Professor: Associate Professors Marc H. Raibert, Stephen A. Ward, and John L. Wyatt. Assistant Professor Rishiyur S. Nikhil was promoted to Associate Professor.

We also welcomed three new faculty members. After a distinguished research and academic career at Xerox Research Center, Digital Equipment Corp., and Stanford University, Leonidas J. Guibas joined our department as Professor of Computer Science. Qing Hu received his PhD at Harvard, did postdoctoral work at the University of California and Lawrence Livermore Laboratory, and joined the department as Assistant Professor of Electrical Engineering. Gregory M. Papadopoulos received his PhD at MIT and is now Assistant Professor of Electrical Engineering and Computer Science.

Faculty members received a number of honors and awards this year:

Professor Dimitri Antoniadis was elected a Fellow of the IEEE.

Professor H. Kent Bowen was the 1990 recipient of the Gordon Y. Billard Award, given for outstanding service performed for the Institute. Professor Bowen was a founder of the interdisciplinary Leaders in Manufacturing Program.

Assistant Professor Srinivas Devadas was named Analog Devices Career Development Assistant Professor of Electrical Engineering.

Institute Professor Mildred Dresselhaus was honored with the National Medal of Science.

Associate Professor James G. Fujimoto was a recipient of the 1990 National Academy of Sciences Award for Initiatives in Research. The award is given to encourage research likely to lead to new capabilities for human benefit, and recognizes Professor Fujimoto's work on optics and lasers for diagnostic uses.

Robert G. Gallager, Fujitsu Professor of Electrical Engineering, was the recipient of the 1990 IEEE Medal of Honor in recognition of his outstanding contributions in the fields of communication, information theory, communication theory, and data networks.

Associate Professor David K. Gifford was named Karl R. Van Tassel Career Development Associate Professor of Computer Science.

Professor Berthold K. Horn was awarded the prestigious Rank Foundation Prize for his pioneering work that led to practical systems for computer vision.

Assistant Professor Thomas F. Knight was honored with this year's Graduate Student Council Teaching Award.

Professor Emeritus Joseph C. R. Licklider was a recipient of a 1990 Common Wealth Award for Distinguished Service for outstanding achievement in the invention category. He was recognized for "his work in improving the human-computer dialogue" and for his role "in developing such concepts as time sharing, virtual memory and resource sharing."

David A. McAllester was named Esther and Harold E. Edgerton Assistant Professor of Computer Science.

The prestigious Japan Prize was awarded to Professor Marvin Minsky. The Japan Prize recognizes scientists who contribute to the "peace and prosperity of mankind" through original and outstanding achievements in science and technology. Professor Minsky is considered the father of the field of artificial intelligence and was a founder of the Artificial Intelligence Laboratory. He was cited for his "establishment of artificial intelligence as a new discipline and the proposal of its fundamental principles." Professor Minsky was also honored this year as the first holder of the Toshiba Professorship of Media Arts and Sciences.

Professor Joel Moses was named Dugald C. Jackson Professor of Computer Science, and was elected a Fellow of the IEEE.

Professor L. Rafael Reif was named the new director of the Microsystems Technology Laboratories.

Professor Arthur C. Smith was named by the Provost to serve as Acting Dean for Student Affairs. Professor Smith has served as chair of the Committee on Academic Performance, the Committee on Privacy, the Committee on Student Affairs, and the Committee on Educational Policy. He is a former chair of the faculty and a member of the Minority Student Issues Group, as well as the 1987 winner of the Gordon Y. Billard Award.

Professor Henry I. Smith, a leading figure in research to improve the performance of electronic devices, was named Joseph F. and Nancy P. Keithley Professor of Electrical Engineering. Professor Smith is widely respected as the originator of x-ray lithography. He was also elected to the National Academy of Engineering.

The department welcomed two visiting faculty members who participated in our teaching and research activities:

Visiting Professor Charles S. Burrus, chair of the Electrical and Computer Engineering Department at Rice University, taught and pursued research in signal processing with Professors Alan V. Oppenheim and Jae Lim.

Patricia Maes, Visiting Assistant Professor, is a Senior Research Assistant at the University of Brussels. She spent the year teaching undergraduate subjects and conducting research at the Artificial Intelligence Laboratory with Professor Patrick Winston and Associate Professor Rodney Brooks.

Several faculty were away this year:

Professor Alvin Drake spent the year revising his textbook on probability theory and conducting research on statistics applied to manufacturing.

Professor Lawrence Frishkopf spent the year working on the problems of cochlear micromechanics.

Professor Joel Moses spent the academic year pursuing research at the Harvard Business School.

Associate Professor Terry Orlando was at Delft University of Technology during the fall term working on the physics and technology of mesoscopic electronic systems, superconducting, and semiconducting.

During the spring term Professor Jack Ruina explored new research at Stanford University.

Professor Jerome Saltzer was in California during the spring term conducting research in the field of computer systems and communications.

During the fall term Professor Arthur C. Smith was at the University of Auckland writing in the field of semiconductor devices and exploring new research.

During the spring term Associate Professor Charles Sodini was at the University of California, Berkeley and at Stanford working on IC technology and the use of the MIT Database Accelerator System for high speed simulation.

Associate Professor Peter Szolovits spent the spring term at Stanford, writing about artificial intelligence in medicine and developing new research ideas about the future of the field.

During the spring term Professor Richard Thornton participated in a new initiative in the field of magnetic levitation for transportation sponsored by Senator Daniel Patrick Moynihan, and finished a textbook on electronic circuits.

The department notes with sadness the loss of four beloved colleagues and friends.

Professor Emeritus Yuk Wing Lee, internationally known for his work in statistical communication theory, died this year. Professor Lee offered the first graduate subject ever given on the subject of statistical communication theory. He based his class on the ideas of Dr. Norbert Wiener, with whom he studied and collaborated. Professor Lee's long association with Wiener led to the publication of Wiener's book, Nonlinear Problems in Random Theory, which was made by recording and photographing Wiener's presentation of the material before a group of students. Professor Lee was the author of Statistical Theory of Communication and of many articles and papers. He was awarded an honorary doctorate by the Catholic University of Louvain, Belgium.

Distinguished Professor Richard B. Adler died after being struck by a car near his home. Professor Adler made major educational contributions to the Institute and to the department. He co-authored two electromagnetics textbooks which were used in the EE undergraduate core curriculum. In 1960 he established the Semiconductor Electronics Education Committee, which totally reshaped the teaching of electronics in the US to account for the introduction of the transistor. He became Associate Department Head in 1978, and in that role was largely responsible for securing support for the Microsystems Technology Laboratories; when he stepped down as Associate Department Head he became Co-Director of MTL. In 1986 he received the prestigious IEEE Education Medal. His friendly nature, endless energy, and sharp insight earned the respect and affection of all who knew him.

One of MIT's most colorful and visionary faculty members, Institute Professor Emeritus Harold E. "Doc" Edgerton, also died this year. Doc transformed the strobe light from a laboratory oddity into a tool for science, industry and photography, and was a friend, mentor and inspiration to countless MIT students. The strobe systems he developed in World War II enabled the Allies to take nighttime aerial photographs, and he was a pioneer in deep-sea photography and sonar. He designed and developed the cameras and lights used by his friend and collaborator, Jacques-Yves Cousteau. Among Doc's many honors and awards were the National Medal of Technology; the Gold Medal of the National Geographic Society; the Modern Pioneer Award; the Potts Medal of the Franklin Institute; the Silver Progress Medal of the Royal Photography Society; the Progress Award of the Society of Motion Picture and Television Engineers; the E.I. DuPont Gold Medal; the Albert A. Michelson Medal; and the Richardson Medal of the Optical Society of America. Just before his death, Doc was awarded two more honors: the Pomerance Award of the Archaeological Institute of America, and the commemorative medal issued by the Ministry of Culture of Czechoslovakia in honor of the 150th anniversary of the invention of photography. Throughout his career, Doc never lost his enthusiasm or his sense of adventure: "Work like hell," he said, "tell everyone everything you know, close a deal with a handshake, and have fun."

Professor Emeritus Joseph C. R. Licklider, one of the pioneers of what we know today as computer science, also passed away. Professor Licklider established the Information Processing Techniques Office, now known as ISTO, at ARPA in 1962. This office has supported computer science research at all the major universities. Professor Licklider had a distinguished career as a teacher at Harvard and MIT, and as a researcher at Bolt, Beranek and Newman; at ARPA; and at IBM. He served our department as Associate Director of Project MAC, and later as Director of the Laboratory for Computer Science, as Project MAC came to be known. He retired from the faculty in 1985.

PAUL PENFIELD, JR.

Department of Materials Science and Engineering

SUMMARY

The academic year 1989-1990 has been an important one for our field and for our Department. Public awareness of the importance of the field has continued to grow. Allan Bromley, Science Advisor to the President, has made it clear that his office views Materials Science and Engineering as a prime enabling technology for the future. He has also noted the relative weakness of synthesis and processing in the United States. Our Department has long emphasized this critical aspect of our field.

We were gratified, but not surprised, to be listed as the top Department in Materials Science and Engineering in the country, in the recent US News and World Report survey.

We have added two new faculty members to our ranks this year, and a third will join us in the fall. Dr. Manuel P. Oliveria joined us as Assistant Professor of Ceramics last fall. Beginning July 1 he will hold the Elisha Gray II Career Development Professorship. Dr. Uday B. Pal joined us in April of this year as the John Chipman Assistant Professor. Dr. Kirk D. Kolenbrander, now at AT&T Bell Labs, will join us in September as Assistant Professor of Electronic Materials.

Our undergraduate curriculum revision continues to make progress. We are pleased with increasing student interest in our Department. At the graduate level, the high priority we have placed on obtaining graduate fellowships has begun to pay important dividends in graduate recruiting. This, plus other vigorous efforts of the Graduate Committee, has resulted in a significant increase in acceptance of us by students whom we admit. It has also resulted in a remarkable increase in the percentage of domestic students in our incoming class.

A major Departmental event during this academic year was the John F. Elliott Symposium in Chemical Process Metallurgy, held on June 10 to 13. This symposium was held under the auspices of the Iron and Steel Society, organized by Dr. George St. Pierre and Dr. Peter Koros, with a Committee including Professor Thomas Eagar and Professor Julian Szekely of this Department. One hundred and seventy-two individuals from throughout the world, many of them former students, attended. The symposium honored John and his illustrious and productive career; it also marked his 70th birthday. I am happy to report that John's 70th birthday falls after July 1, and so he will not retire until June of 1991.

THE UNDERGRADUATE PROGRAM

We now enter the second year of our five year initiative for undergraduate curriculum revision and textbook writing. The initiative stems from a decision taken at a day-long meeting of the faculty in December of 1988. During this first year we have seen substantial progress in developing cohesiveness in our undergraduate core subjects, eliminating overlapping

material, and extending coverage where appropriate. Major changes have been made in our two introductory subjects in thermodynamics and kinetics, by a team led by Professors Eagar and Ragone. Professors Allen and Thomas together have revised our first course in structure of materials to include broader coverage, especially of polymers. A team comprising Professor Rose, Dr. Livingston and Dr. O'Handley is in the process of a comprehensive reorganization of our first subject in electronic properties of materials.

The Undergraduate Committee has assumed a stronger role than was previously the case, both in setting broad goals for the undergraduate curriculum, and in supervising curriculum content.

Our undergraduate enrollment remains at historically high levels, and we are pleased to see what appears to be a significant increase in size of the sophomore class of academic year 1990-1991. We believe that the growing importance of the field of materials will provide ample career opportunities for increased numbers of undergraduates. We therefore intend to continue our extensive recruiting efforts during the coming academic year. This year these efforts included 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 twenty-five 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 1990 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 the percentage of students who have accepted our offer of admission has now risen to 60%, as compared with only 50% in recent past years. Perhaps even more remarkable is that the percent of domestic students we anticipate in our incoming class of the fall of 1990 has increased from 56% percent of the class in 1989 to an estimated 70% in the fall of 1990.

We attribute the improved percentages noted above to two important factors. One is an increasingly 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 fundraising priority of the Department. We were able, for the class of graduate students to be admitted in the fall of 1990, to offer sixteen Departmental fellowships of one semester or more, and we hope to be able to maintain or increase this number of fellowship awards in the years immediately ahead.

Approximately 29 percent of our graduate students are women. However, we are noting a trend in which a smaller percentage of the entering women are continuing to the doctorate than are the entering male students. This is also true of domestic male students who are deciding increasingly to stop their education at the master's degree.

In response to the above trends, one of our goals is to develop a professional master's degree, hallmarks of which will be synthesis, complexity, and teamwork, with a possible emphasis on processing and manufacturing. We expect such a program to be attractive to a broader group of domestic students. We believe that this goal fits directly within the recommendations of the MIT Commission on Productivity and the long-range goals of the School of Engineering.

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, as of February 1990, was:

<u>Degree Program</u>	<u>Percent of Total Graduate Students</u>
Ceramics	17%
Electronic Materials	22%
Materials Engineering	21%
Materials Science	8%
Metallurgy	18%
Polymers	14%

Approximately a quarter of our students in Materials Engineering were enrolled in our Technology and Policy Program or our Leaders for Manufacturing Program. A third of our Polymer students were enrolled in our Program for Polymer Science and Technology (PPST). Each of these programs is interdepartmental in nature.

Our research and educational programs in materials processing and materials manufacturing continue to be strengthened and expanded. Over 25 percent of the students in the Leaders for Manufacturing Program are enrolled in our Department, and a similar number have advisors for their industrial internships from among our faculty. Professor H. Kent Bowen, as the Leaders for Manufacturing Co-Director, as well as Professors Thomas W. Eagar and Stuart B. Brown, spend considerable time on the Leaders for Manufacturing activities while Professor Julian Szekely, Joel P. Clark, and Merton C. Flemings have each participated in significant ways.

The publication of the National Academy of Sciences report on "Materials Science and Engineering in the 1990's" this past fall, has generated considerable interest, nationally and at MIT, in enhancing our programs in Materials Processing. We are continuing to seek funding for cooperative university-industry research initiatives in this area.

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 seven 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; Merton C. Flemings, Toyota Professor of Materials Processing; Uday B. Pal, John Chipman Assistant Professor; Edwin L. Thomas, Morris Cohen Professor of Materials Science and Engineering; and Bernhardt J. Wuensch, TDK Professor of Materials Science and Engineering.

In addition to the foregoing, the Department is proud to have received two additional endowed chairs, to be filled during the coming academic year. One of these is the Richard P. Simmons Professorship in Metallurgy, established by Allegheny Ludlum Corporation in honor of the retirement of Richard P. Simmons, '53, Chairman and Chief Executive Officer of Allegheny Ludlum. Our second new endowed chair is the Thomas Lord Professorship of Materials Science and Engineering, established by the Lord Foundation in recognition of the achievement of Thomas Lord in building a major US corporation based largely on advanced materials.

Term chairs, especially those held by junior faculty members, are of immense value in building their careers. Chairholders and chairs for the academic year 1989-1990 were: Ronald G. Ballinger, Carl Richard Soderberg Associate Professor of Materials and Nuclear Engineering; Stuart B. Brown, Richard P. Simmons Assistant Professor of Materials Manufacturing; Peggy Cebe, Esther and Harold E. Edgerton Assistant Professor of Polymer Physics; Michael J. Cima, Norton Assistant Professor of Ceramics Processing; Thomas W. Eagar, Leaders for Manufacturing Professor of Materials Engineering; Nicole Herbots, Carl Richard Soderberg Assistant Professor of Electronic Materials; Andreas Mortensen, ALCOA Assistant Professor of Mechanical Metallurgy; Michael F. Rubner, Class of '57 Associate Professor of Polymer Physics. In addition, Professor Manuel P. Oliveria will hold the Elisha Gray II Career Development Chair for the coming academic year.

FACULTY

During this academic year Professor H. Kent Bowen received The Gordon Y Billard Award, an award presented for special service of outstanding merit performed for the Institute. This award was in recognition of Kent's major achievement in initiating and co-directing the new important Leadership for Manufacturing Program at MIT. Professor Stuart B. Brown received a Leaders for Manufacturing Junior Faculty Grant. Professor Morris Cohen was awarded an honorary doctorate from Northeastern University. Professor Thomas W. Eagar was elected a Fellow of ASM International and appointed as Houdremont Lecturer of the International Institute of Welding. This lecture is the highest scientific honor conferred by the International Institute of Welding.

Professor John F. Elliot received the Tawara Gold Medal of the Iron and Steel Institute of Japan. He was further honored by the John F. Elliott Symposium on Chemical Process Metallurgy referred to earlier in this report. Professor Merton C. Flemings received The Minerals, Metals & Materials Society (TMS) 1990 Leadership Award. Professor Michael F. Rubner received The Graduate Student Council Teaching Award for this Department. This award is given for excellence in teaching, particularly with respect to teaching of and interaction with graduate students. He also received the Institute-wide Everett Moore Baker Memorial Award for Excellence in Undergraduate Teaching. This award is presented in recognition of exceptional interest and ability in the instruction of undergraduates.

Emeritus Professor Cyril Stanley Smith received this year the new Acta Metallurgica J. Herbert Hollomon Award for outstanding contributions to understanding the relations between materials technology and society. Professor Harry L. Tuller was elected an American Ceramic Society Fellow, received a Fulbright Travel Grant Award for his sabbatical, and was appointed Visiting Professor, Universite Pierre et Marie Curie, Paris for the academic year 1989-1990. Professor August F. Witt received the first Amar Bose Teaching Award for his sustained and successful efforts in undergraduate teaching. This Engineering School award was established during the last year with a gift from the Bose Corporation and the Bose Foundation. The selection of Professor Witt as the first recipient recognizes his superb accomplishments over a fifteen year period in teaching chemistry of the solid-state and materials science and engineering to undergraduates. His accomplishments have been great, and it is gratifying to see them acknowledged in this important way.

Professor Benjamin L. Averbach reached his retirement age of 70 during this academic year, and Professor Harry C. Gatos also retired. Both now join our ranks of Professors Emeriti. Both will continue to participate in Departmental activities.

The Department's teaching and research activities were much strengthened during the past year by the appointment and reappointment of a number of visiting and adjunct faculty. Dr. Lionel C. Kimerling, of AT&T Bell Labs, continued to teach his graduate course in compound semiconductors as an Adjunct Professor in our Department. Dr. Robert A. Laudise, also of AT&T Bell Labs, has continued as an Adjunct Professor, and is actively participating in a number of research programs. Both Dr. Kimerling and Dr. Laudise have provided this support to our Department under the sponsorship of AT&T Bell Laboratories. The opportunity to work closely with these two scholars is a significant contribution to our Department.

Visiting Professor Harold D. Brody has continued his work on solidification principles, and is participating in a major effort to grow single crystals of high temperature superconductor oxides. Professor David V. Ragone has assisted in teaching kinetics in our undergraduate program as well as working with Professor Joel P. Clark in the Materials Systems Laboratory. Dr. James Livingston, formerly of General Electric Research Laboratories, will continue with us as Lecturer aiding in development of our electronic materials undergraduate subject.

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 Jamie Wong (President), Ken Battige (Vice President), Richard Wong (Treasurer), and Anahita Jamashidi (Secretary). New Officers elected in spring 1990, are: Richard Wong (President), Michelle Hou (Vice President), Anahita Jamashidi (Treasurer), and Albert Cheng (Secretary).

Michael A. Capano was elected President of the Graduate Student Council, and received this year the William L. Stewart, Jr. Award for his outstanding contributions to extracurricular life at MIT. Robert B. Calhoun received the Best Senior Thesis Award of the Department. Ms. Julie A. Tsai and Ms. Chrysanthe D. Terwilliger were awarded the John Wulff Award for Excellence in Teaching for the academic year. David Emero was named "TRW Undergraduate Scholar" for his undergraduate research on a performance polymer.

Shu Tung received the TRW Award for Outstanding Undergraduate Research. Marius Klopppers received the H. H. Uhlig Award of the Boston Chapter of the National Association of Corrosion Engineers. Paula Hammond received the Theophilus Sorrell Outstanding Graduate Student Award, awarded by the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers, sponsored by Eastman Kodak.

K. Winey received a Materials Research Society Student Award. Students elected to Tau Beta Pi are: Maureen T. Fahey, Angeline M. Ondaatjie (Class of '90); and Laura L. Beecroft, Bonnie Koao, Lester Liu, Terry C. Totemeir, Kellie C. Wills, Richard P. Wong and Jane I. Song (Class of '91).

Newly elected members of the Graduate Materials Council (GMC) are: Olof Hellman (Chairman), Chrysanthe Terwilliger (Vice Chairman), Isako Hoshino (Treasurer), Naomi Super and Bruce Pint (DCGS Representatives), Fred Haubensak and Livia Racz (Social Chairs), Donna McCoy and S. S. Papa Rao (MESSeminars), and Tami Fletcher (MPC Representative). GMC continued its seminars and monthly socials, including a summer picnic. It continued to undertake the supervision of the arduous task of course evaluations.

The MIT Student Chapter of the Materials Research Society has the same officers as last year. They are Sergio Ajuria (Chair), Ann Westerheim (Secretary), and Jerry Floro (Treasurer). The group organized a series of lectures on Materials Research in Industry, with speakers discussing opportunities in materials research at their respective companies.

Fellowship Awards for one or more semesters were held during academic year 1989-90 by 36 students. These were: Naomi A. Super, National Defense Science and Engineering; Heather B. Shapiro, Hertz Foundation; Bruce L. Carvalho, Exxon; Sengshiu Chung and Sam P. Sido, IBM; Marlene A. Spears, Eastman Kodak Co.; Jerome B. Friler, Pratyush Kumar, William D. MacDonald,

Susan L. Schiefelbein and Donna S. McCoy, Materials Processing Center Industrial Collegium; Julia C. Putnam, Michele Sequeira, Richard A. Krueger, Benjamin R. Samuels and Julia S. Schneider, Leaders for Manufacturing Program; Susan P. James and Christine E. Weigand, PPST; Ariel J. S. Traiber and William D. MacDonald, Roberto Rocco Graduate Fellowships; Brian R. Bennett, USAF Universal Energy Systems; Mariflor Salas-Morales and Naomi A. Super, MMR II; Jerrold A. Floro, Sergio Ajuria, Sossina Haile and Mary Matthiesen, AT&T Bell Laboratories; Steven A. Attanasio, Michael Liberatore and Elliot M. Schwartz, NDSEG; Sharon L. Furcone, NSF; Jeri Ann Ikeda, Angela S. Longo, and Chrysanthe Terwilliger, ONR; Yaping Liu, Shaw Graduate Fellowship; Yuying Tang, Wang Laboratories; Patricia A. Cullen, American Chemical Society.

FACULTY AND STAFF RESEARCH ACTIVITIES

During the past year, Professor Samuel M. Allen continued his studies on intermetallic compounds and antiphase boundaries. Professor Robert W. Balluffi used hot-stage electron microscopy to study grain boundary phase transitions. His major effort of this year has been writing the textbook Internal Interphases in Crystalline Solids in collaboration with Adrian Sutton of Oxford University. Dr. Paul D. Bristowe has performed a large-scale molecular dynamic simulation of grain boundary migration in metals, and identified a local conservation shuffle mechanism to explain migration without the participation of grain boundary dislocations.

Professor Stuart B. Brown has developed a new constitutive model for the rheology of semi-solid slurries that employs fundamental principles to represent complicated flow behavior. He has also clarified factors effecting weld quality when welding large, three-dimensional structures. Professor Peggy Cebe has used Synchrotron X-radiation to perform real-time studies of crystallization kinetics and melting in high performance polymers. Results confirm the model she has developed to explain the origin of multiple melting endotherms which occur after crystallization at different undercooling conditions. Professor Yet-Ming Chiang's research on ceramic superconductors has shown that electrical junctions associated with grain boundaries are different in different oxide systems, thus pointing a direction toward controlling the grain boundary properties through additives and processing conditions. In his work on the commercially important barium titanate thermistor, the origin of electrically active grain boundary defects necessary for the positive-temperature-coefficient of resistance has been identified.

Professor Michael J. Cima developed a chemical technique to prepare epitaxial films of $\text{Ba}_2\text{YCu}_3\text{O}_{6.9}$ superconductor; these have critical current densities that exceed 10^6A/cm^2 at 77 K. He also developed a new ceramic forming technology for the fabrication of complex shapes that appears to be the first demonstration of a colloidal process where body-forces are used in forming. Professor Joel P. Clark's research in the Materials Systems Laboratory focused on assessments of the competitive environment and market for materials in areas including autobody panels, net-shape processing, and high temperature aerospace materials. A new initiative, the International Materials Program, was founded with support from the Government of Portugal. In Professor Morris Cohen's work, important advances have been achieved with regard to martensitic

transformations. A new multiactivation treatment of autocatalytic nucleation permits quantitative modeling of the entire course of a martensitic transformation.

Professor Thomas W. Eagar has shown that a significant amount of thermodynamic information can be extracted from experimental diffusion data. Although these different data were linked theoretically over forty years ago, a practical linkage was not previously available. Professor John F. Elliott's research continues on the relationships between physical and chemical properties of respirable dusts of silica and other inorganic particles and their biological effects. His test program for the 1.5 Mw test furnace for smelting ferrochromium that is located at the Macalloy Plant in Charleston, SC, is now in operation. Professor Merton C. Flemings' research continues on directional solidification of high temperature superconductors, and on dynamics of solidification of undercooled metal alloys. A major focus of Professor Nicholas J. Grant's research is on spray deposition of plane carbon, low carbon steels as a substitution for current thick slab continuous casting. Work is also underway to evaluate the effects of high levels of common impurity elements in rapidly solidified steel.

Dr. John Haggerty's current research focuses on the processing and properties of monolithic and composite ceramics made from high purity ceramic powders and polymeric precursors. Additionally, 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 has completed development of The Combined Ion and Molecular Beam Deposition Laboratory, and in her research has demonstrated the capability of growing at room temperature thermally unstable GaAs oxide phases using direct deposition from an oxygen ion beam. Professor Keith H. Johnson continues to develop his theory of superconductivity, and is writing a treatise on the subject. Professor Ronald M. Latanision's group is pursuing a computational materials program which allows one to predict the properties of solid state systems through computer aided simulation. Interfacial properties have been predicted, and work is in progress to extend the approach to the study of atomic scope and embrittlement phenomena.

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, together with Professor Dorothy Hosler, published a major monograph, Axe-Monies and their Relatives, which describes the archaeology, the ethnohistory, and the metallurgical technologies behind the production and use of what may be considered the first system of primitive money in the New World.

Theoretical research in Professor Andreas Mortensen's group on macrosegregation in cast fiber reinforced metals has received experimental confirmation both from work at MIT and in collaboration with industry. Research on fracture of fiber and particle reinforced metals has provided insights on the roles of reinforcement geometry and matrix properties in toughening these materials. New research initiated this year includes diffusion bonding studies for fiber reinforced titanium and titanium

aluminide, and solidification studies on fiber reinforced metals. Dr. Robert O'Handley has made the first experimental determination of magnetoelastic coupling at a surface, and found the coupling to be much stronger there than in the bulk. His three year program on magnetic quasicrystals is winding down with the publication of a major review chapter "Magnetism in Quasicrystals." Professor Manuel P. Oliveria is establishing a sputtering facility for preparing nanoscale composites with novel optical and magnetic properties.

Professor Regis M. Pelloux's research work is centered around the study of fatigue and fracture behavior of metals. Two studies were completed this year, one on fatigue cracking in an aircraft disc alloy, and the second on the performance of aluminum alloys on wind turbine technology. A new program on the ageing of aircraft structures was initiated. Professor David V. Ragone undertook a project on economic development in Portugal. Professor Robert M. Rose, in collaboration with Professor Donald R. Sadoway continued work on electrochemical modulation and electrosynthesis of high temperature superconductors. Professor David K. Roylance studied the durability of filled elastomers subjected to large cyclic loads, the role of chain extension versus crosslinking in high-temperature polymer matrix resins, the role of processing variables on the morphology and properties of toughened polyamide resins, and the modeling of flow and heat transfer during infiltration processing of composites.

Professor Michael F. Rubner's group continues to pioneer the development of Langmuir-Blodgett thin films of electrically conductive polymers. Novel multilayer thin film structures with unusually large dielectric constants and highly anisotropic electrical conductivities have recently been fabricated. In addition, these new films have been utilized to form working field effect transistors (FETS) and related microelectronic devices. Professor Kenneth C. Russell made significant progress in theoretical and experimental investigation of wetting of ceramic fibers by metallic melts. Professor Donald R. Sadoway's research was marked by continued progress in the development of a nonconsumable anode for the Hall cell, as concepts developed earlier were tested in laboratory scale cells at MIT and in pilot cells in the laboratories of a domestic aluminum producer. New discoveries were made in the use of cryogenic electrochemistry as applied to cuprate superconductors.

Professor Edwin L. Thomas pioneered the use of HRTEM to map out the director field about disclinations in thermotropic liquid crystalline materials. This has enabled direct measurement of the elastic anisotropy as a function of radial distance from the defect core, providing the first insight on the influence of molecular properties on disclination core structure. Professor Carl V. Thompson demonstrated and characterized epitaxial grain growth, a new mechanism for growth of epitaxial thin films. With Professor David Rudman and students, he has also demonstrated that nucleation and growth of new phases at interfaces can be detected and analyzed using calorimetric techniques. In addition, he extended earlier work on computer simulation of grain growth in thin films.

Professor Harry L. Tuller investigated the transport properties of a number of high temperature superconducting cuprates at elevated temperatures. His research on fast ion conducting glasses demonstrated the ability to simultaneously optimize ionic conductivity and chemical stability. For the first time, oxygen defect profiles were examined in oxides by a photoelectrochemical method. Professor John B. Vander Sande has continued his research on the processing of high transition temperature superconducting oxides by oxidation of metallic precursors. Melt spinning, melt dipping and a new technique termed "melt writing" are the processes used to create objects from these alloys.

Professor August F. Witt, using computational image analysis in conjunction with NIR transmission microscopy, established that compositional fluctuations in doped GaAs are much larger than previously reported. The effects of compositional and stoichiometric non-uniformities on implant activation and long term stability of laser structures are being investigated. Professor Ionnis V. Yannas continued his studies of regeneration of the rat sciatic nerve with surprising results relating to the speed and completeness of regeneration. In addition, studies of the mechanism by which "artificial skin" induces regeneration of skin have suggested that the porous resorbable matrix may act as if it were a very crude analog of a developmentally active extracellular matrix.

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 will have a central role in addressing the challenges of the next decade 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 and measurement 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 480 undergraduates. In the graduate program approximately 45% of the 420 full-time students are enrolled in the PhD program. The strong demand for students graduating with SB and SM degrees has continued as has the demand for Ph.D graduates interested in engineering education, as universities respond to national educational and research needs.

Special effort has been focused on undergraduate and graduate curriculum development in the department. This past summer a workshop was conducted in which faculty reviewed the undergraduate curriculum. As a result of this review, task forces have been formed to develop new materials for the curriculum which will be introduced in Fall 1990.

This spring the first class of 20 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 - - New Product Development - - 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. During the last year, increases in research effort have occurred in the manufacturing, design, and systems areas while support for other areas in the Department has remained relatively constant. Research support from industry has continued to be significant, representing approximately 25% of the total research administered through the Department.

Effort has continued 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 for our undergraduate laboratory in measurement and instrumentation.

Additionally, the Fluid Mechanics Laboratory has been renovated to provide enhanced capabilities in fluid mechanics research related to fundamental flow studies and to applications in the biomedical and environmental engineering areas.

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 Bora Mikic 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-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 undergraduate enrollment continued at levels comparable to the past few years with a total enrollment of more than 480 students. The new sophomore class of 149 included 27 women and 16 black students.

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. Eighteen sophomores were enrolled in II-A.

In the 1989-90 academic year the Department awarded 154 SB degrees with 120 in Mechanical Engineering (II), 10 without specification (II-A), and 24 in the Internship Program (II-B).

Engineering Internship Program

The tenth anniversary has occurred for the Engineering Internship Program which started in 1978 by placing a total of 31 sophomores from engineering departments at 12 different companies. Over the 10 years, mechanical engineering participation has increased, typically forming one-half of each new group entering the program. We have averaged 26 students entering the program each year, which represents an average of 18% of our eligible sophomores. Currently about three-quarters of the mechanical engineering sophomores entering the program continue for a graduate degree.. In 1989, 81 of the total of 154 students working at the 28 participating companies are from the Department, including 21 graduate students completing SM degrees..

Undergraduate Curriculum Development

During the year a group of faculty reviewed the current undergraduate curriculum. As a part of this effort, a student forum was held in which the current undergraduate curriculum was discussed in depth with students in the Department. As a result of this overall review effort, task forces have been formed to provide a stronger integration of the core engineering science subjects in the curriculum, to provide an improved distribution in the curriculum of skills such as teamwork, life-long learning and oral, written and visual communications and an understanding of the context of engineering in modern society, to evaluate the role of capstone subjects in design and experimental engineering and to consider the implications of a combined five-year SB/SM program. These task forces will work in the summer of 1990, and the initial results of their recommendations are expected to be implemented in the fall.

Faculty have also continued in the development of the core manufacturing subject and have 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 subject will be offered next year, 2.33 Finite Element Applications in Mechanics and Materials, taught by M.C. Boyce and D.M. Parks.

Student Organizations

The Student Chapter of the American Society of Mechanical Engineers under the leadership of its officers: Mark Strong, President; Felipe Calderon, Vice-President; and Chris Harris, Treasurer continued to develop student professional activities in the Department. Professor Igor Paul served as the Faculty Advisor to the nearly 139 ASME student members.

Black ME is an organization of students which provides a supportive environment for minorities in the Department. Membership in Black ME has continued to be strong with over 40 students. This past year the organization provided academic support in subject reviews, sponsored corporate presentations and had professional engineers make presentations to its membership. The organization was ably led by Robert Dodd, President; Andrew Frazier, Vice-

President; Cheryl Gill, Secretary; and Me'lani Labat, 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: Mark Strong, President; Don Lee, Vice President; Andrew Fusco, Corresponding Secretary; and Dheera Ananthakrishnan, 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: Christian Passow, President; Alex Denner, Vice-President; and Peter Graham, Treasurer. The group organized two tours to industrial manufacturing companies

Student Awards

Many undergraduates in the Department were recognized for academic and athletic excellence, engineering creativity, and community service.

The National Science Foundation awarded fellowships to Allison Arnold, Tidbar Shalon, Amy Luong, Cindy Mok, and Lisa Louie.

Luis De Florez Awards were made to Elisabeth Stock, Penny Plummer, Dora Schaefer and Tidhar Shalon.

The Department Service Award was awarded to Renee F. Picard.

Goodyear Tire and Rubber Co. Awards were presented to Dong-Chul Choi, Thomas P. Knight and Ariana Yuen.

Peter Hinze was given the Whitelaw Prize for innovative and inspiring design.

Aaron Flores and William Singhose shared Robert L. Hallock Awards.

AMP, Inc. Awards were given to Allison Arnold and Wendy Muhlenkamp.

Mark Strong received the ASME Student Section Service Award and the International Gas Turbine Institute Award.

The Wunsch Foundation Silent Hoist and Crane Awards were given to Charles C. Abnet, David B. Davies, Klaus Kremmin II, Anton C. Pil, Alexander T. Chen, Christopher J. Foley, Victor Pellicier, and Philip A. Villars.

Jee-Lian Yap received the Louis Sudler Prize in the Arts.

Members of the MIT Chapter of the National Society for Black Engineers received honors and recognition for notable accomplishments. Andrew Frazier was elected Chair, and Gretchen Matlock, Secretary, of Region I for the coming year.

GRADUATE PROGRAMS

Organization

The graduate program is directed by Professors Ain A. Sonin, Graduate Policy and Registration Officer, and Triantaphyllos R. Akylas, 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 1989 was 420 full-time students including 56 women, 7 black, 6 Hispanic, and 19 Asian-American students. In September 1989, 213 new students were admitted from 544 applicants, with 133 students registering.

In 1989-90 the Department awarded 118 SM degrees (of which 12 were combined SB/SM degrees), one Mechanical Engineer degree, and 34 doctoral degrees.

In Fall 1989, 99.8% of all graduate students received support from the Department, MIT funds, fellowships, the government or industry. Seventy percent of the graduate students were 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. This spring the first class of 20 students has graduated from the Program. Many of these students have taken subjects in the Department in the areas of manufacturing processes, manufacturing automation, and manufacturing 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.

A new subject has been developed entitled 2.763J Hyperthermia: Biology, Technology, and Cancer Therapy which will be taught by P.P. Lele, H.F. Bowman, and T.S. Herman next year.

Student Awards

Scott M. Maxwell was awarded the **Carl G. Sontheimer Prize for Innovative Design by an Outstanding Student in Mechanical Engineering**.

Krisztina Holly was granted the **Martin Fellowship for Engineering Design**, and **Akhil Madhani** 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. Approximately one-half 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 and systems and design.

The total volume of sponsored research for the 1989-1990 year administered through the Department increased by over 20 percent to \$8.3 million. Additional sponsored research of an approximately equal amount is administered through inter-departmental 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 major program areas of manufacturing, 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. Professor Steven Kim has developed a research program for management of manufacturing systems using artificial intelligence techniques, 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 composites 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, a laboratory facility developed under the joint auspices of the Mechanical and Civil Engineering Departments, 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 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. Hault.

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 new research program has been initiated by Professor Markus L. Flik to determine the heat transfer characteristics of thin film super-conducting materials.

Research focused on the environment includes the work of Professors Ronald F. Probst and Patricia Renaud who are 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.

A new consortium in the structural acoustics area 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 a research program 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 and his colleagues have 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 and Dr. Dana R. Yoerger of the Man Machine Systems Laboratory have made significant progress in the development of undersea remote manipulation in research coordinated with the Woods Hole Oceanographic Institute. Professor David C. Gossard in the Computer-Aided Design Laboratory 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 through research conducted in the Center for Information-Driven Mechanical Systems. Professor Harry Asada has initiated research on issues of learning/teaching in robotic systems, while Professor Jean-Jacques Slotine has demonstrated methods of non-linear 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 non-linear actuators .

In transportation, Professor David N. Wormley has continued research developing identification techniques for the evaluation of non-linear suspension characteristics in vehicles, as well as non-linear 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 and industrial organizations.

During the last year the Brit and Alex d'Arbeloff Endowment Fund was established in the Department to support and encourage innovation in engineering design education. The Fund will support a junior faculty career development chair as well as provide fellowship support for graduate and undergraduate students. The Karl Chang Innovation Fund was also established in the School of Engineering and will initially be directed to supporting the development of the New Products Design education program.

The Ralph and Eloise Cross Professorship in Manufacturing has been established in the School of Engineering with Professor Nam P. Suh the initial appointee to the Chair.

The Alcoa Corporation continued its support of a term development chair in the Department in the area of manufacturing and materials processing.

A number of companies and foundations have continued to provide grants of unrestricted funds to support faculty and graduate students. 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. Additionally, an equipment grant from Hewlett Packard Corporation has provided new computers for our undergraduate measurement and instrumentation laboratories.

FACULTY AND STAFF

SIZE AND COMPOSITION

On September 1, 1989, there were 58 active faculty; 29 professors, 17 associate professors, (13 with tenure), and 12 assistant professors. The teaching, research, and technical staff fluctuates around 70, more than half of whom are part-time and who are based in another department or outside MIT.

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 are: Professors Klaus-Jurgen Bathe and Ernest Rabinowicz; Bora Mikic and Ain A. Sonin; Woodie Flowers and Warren Seering.

ACCOMPLISHMENTS AND AWARDS

Assistant Professor William K. Durfee received the Graduate Student Council Award for excellent in teaching.

Assistant Professor Markus I. Flik was named the holder of the Lynde and Harry Bradley Foundation Career Development Chair for a two year period.

Professor John B. Heywood was selected to receive the 1990 Soichiro Honda Lectureship by the American Society of Mechanical Engineers.

Assistant Professor Mark J. Jakiela was one of nine MIT young faculty members selected to receive 1990 Presidential Young Investigator Awards by the National Science Foundation. Professor Jakiela was also appointed Flowers Career Development Assistant Professor of Mechanical Engineering.

Assistant Professor Harri K. Kytomaa was appointed as an Esther and Harold E. Edgerton Assistant Professor for a two-year term.

Professor Richard H. Lyon was elected Vice-President of the Acoustical Society.

Robert W. Mann, Whitaker Professor of Biomedical Engineering, was elected President of the National Braille Press which serves the reading needs of blind and deaf-blind people.

Dr. Ronald F. Probst, Ford Professor of Engineering, was named a Fellow of the American Society of Mechanical Engineers. *Physicochemical Hydrodynamics*, a book written by Professor Probst, was selected as one of two outstanding books in engineering in 1989 in the 14th Annual Professional and Scholarly Book Awards sponsored by the Association of American Publishers.

Dr. Michael Rosen received a Distinguished Service Award from RESNA, an interdisciplinary association for the advancement of rehabilitation and assistive technologies.

Professor Derek Rowell was awarded the 1990 Den Hartog Award for teaching excellence.

Dr. Thomas B. Sheridan, Professor of Engineering and Applied Psychology, is President-elect of the Human Factors Society.

Dr. Nam P. Suh was named the first holder of the Ralph E. and Eloise F. Cross Professorship of Manufacturing.

Three Department of Mechanical Engineering faculty members received junior faculty grants from the Leaders for Manufacturing Program. They were Assistant Professors Mark J. Jakiela, Emanuel M. Sachs, and Harry West.

PROMOTIONS

Associate Professor Haruhiko Asada was promoted to full professor effective July 1, 1990.

Associate Professor Rohan Abeyaratne was granted tenure effective July 1, 1990.

Assistant Professors George Chryssolouris and William K. Durfee were promoted to associate professor, effective July 1, 1990.

Dr. Mark Johnson was promoted to Principal Research Engineer, effective April 1, 1990.

NEW FACULTY

Two new faculty were appointed to the Department in the Fall. Professor Jung-Hoon Chun was appointed as Assistant Professor in the Mechanics and Materials Division, and Professor Markus L. Flik was appointed as Assistant Professor in the Thermal/Fluids Sciences Division.

RESIGNATIONS

Assistant Professor Patricia Renaud resigned in the Spring to accept a position with the Lyonnaise des Eaux Corporation in France.

DEATHS

Professor Emeritus Egon Orowan passed away on August 3, 1989. He was an active member of the Department from 1950 to 1968 who made seminal contributions to our understanding of the mechanics of materials.

DAVID N. WORMLEY

Department of Nuclear Engineering

The Department of Nuclear Engineering (NED) has as its mission the provision of the best possible education about the scientific principles, engineering design, and societal implications of peaceful applications of nuclear processes. Over the past few years, the department has had about 22 faculty members, 150 graduate students, and 25 undergraduate students. Their efforts can be approximately divided among four main academic areas: fission (40 percent), fusion (25 percent), radiation science and technology (25 percent), and energy economics and policy (10 percent).

Nuclear fission is currently the source of about 20 percent of electricity generation in the US, 23 percent in the OECD countries, and 17 percent of the entire world. The department's recent research initiatives in this area include the study of the next generation nuclear reactors, the reduction of doses due to corrosion products in the existing power plants, and the improved operation and safety of existing nuclear plants.

Nuclear fusion is being pursued as a long-term energy option. While having decreasing budgets in the past few years, it remains the largest DOE-funded energy research effort in the US. Several international agreements call for the development of fusion as a multi-national program that involves Japan, the Soviet Union, and the European community. The department faculty, participating through the Plasma Fusion Center (PFC), have leading responsibilities in the development of the next experimental fusion machines.

The radiation science and technology area, which includes medical applications of nuclear processes for diagnostics and therapy, has grown significantly over the last few years. The department activities in this area include atomistic and molecular simulation of materials and the development of advanced imaging and tomographic techniques using MRI, PET, and neutron interactions.

Two faculty members were added to the department ranks last summer. Professor Eric McFarland, who will direct the Radiological Sciences Graduate Program, is interested in medical and non-medical imaging science. Professor Jacquelyn Yanch's research includes imaging, therapy, and radiation health physics. She will head the Radiation Health Physics program. Professor Michael Driscoll took early retirement in October 1989; he will continue as a research scientist, working on the in-pile loop projects at the MIT Nuclear Reactor Laboratory.

ACADEMIC PROGRAM

Curriculum changes were introduced in two areas of graduate study--Radiological Sciences and Health Physics. The NED faculty and the Committee on Graduate School Policy (CGSP) approved a proposal submitted by the Nuclear Engineering Department and the MIT-Harvard Division of Health Science and Technology to offer jointly the doctoral degree in the field of Radiological Sciences. This new program, which becomes effective September 1990, will enhance the accessibility of the Harvard medical community for students involved in doctoral research. The second change occurred in the field of Radiation Health Physics. At a recent faculty meeting, the Radiation Health Physics discipline was approved as an NED field of study at the doctoral level.

Professor Jeffrey Freidberg initiated a plan to merge the applied plasma physics and fusion technology tracks. This was motivated by the need to offer a broader education to each track and to make more effective use of our faculty with regard to course offerings.

Updating the plasma teaching laboratory has continued. A new Hollow Cathode Discharge experiment for the plasma laboratory was designed and built by Professor Freidberg and graduate students Tom Hsu, John Urbahn, and undergraduate Joe Sorci. This is the major facility in the laboratory and it worked extremely well during its inaugural semester.

The department undertook an extensive review of subjects in the area of numerical methods and made several changes. It was decided to eliminate two advanced subjects and to combine most of the contents into a single, graduate level subject entitled "Modeling & Simulation." The subject was designed to expose students to a variety of applications of computers in the nuclear field. The subject was first offered in the fall semester, and was taught by Professors Freidberg, Kent Hansen, Lawrence Lidsky, Nathan Siu, and Sidney Yip.

A seminar course designed for students interested in advanced biomedical applications of magnetic resonance was introduced in the spring semester. Professor McFarland was responsible for coordinating the administration of the subject.

A special reading course in the area of medical physiology was presented by Professor Van Wedeen of the Whitaker College. Professor Dieter Sigmar of the PFC offered a special seminar-type course that dealt with a number of research topics of current interest in plasma turbulence and anomalous transport in magnetized plasmas.

A new IAP course entitled Nuclear Power Plant Dynamics and Control was offered for credit. This course was well received and was given as a trial to see if interest in the area might warrant incorporation into the regular curriculum. Organized by Professor David Lanning, it was presented by Professors Allan Henry, Lanning, John Meyer, and Dr. John Bernard.

As a result of Project Athena, a number of NED faculty have obtained Athena workstations in their offices (for course-related use). It is expected that, in the near future, most of the remaining NED faculty will receive Athena workstations and a new cluster of 10 workstations will be made available to NED students.

The Undergraduate Committee chaired by Professor Meyer initiated a review of the curriculum to evaluate ways by which the number of joint undergraduate/graduate subjects can be reduced, and how the breadth of the program can be increased to cover non-medical as well as medical applications of radiation.

A new initiative for studying methods of integration of visualization in engineering education was begun by Professors Lidsky, Yip, McFarland, and Yanch.

A booklet that describes all areas of research offered by the department was updated. The faculty and staff in the area of Radiation Science and Technology produced a brochure describing the RST program and the research interests and activities of individual staff members. From previous experience, this type of literature has proven to be valuable for recruiting purposes.

UNDERGRADUATE ENROLLMENT, HONORS, AND AWARDS

The department has maintained approximately the same undergraduate enrollment over the past few years. Eight men and three women completed requirements for the nuclear engineering bachelor degree during the academic year.

Ms. Renee DuBord was selected by the Scholarship Committee of the American Nuclear Society (ANS) Education Division to receive an ANS Undergraduate Scholarship Award. This award is given yearly to an outstanding undergraduate student in the field of nuclear science and engineering.

Department honors were bestowed upon undergraduates Ms. DuBord and Joseph Sorci. Ms. DuBord received the Irving Kaplan Award for the Outstanding Junior in Nuclear Engineering. Mr. Sorci was honored with the Roy Axford Award for the Outstanding Senior in Nuclear Engineering.

The Institute selected George Poulos as the recipient of the Reinhold-Rudenberg Memorial Prize for the best senior thesis in the Institute. His thesis in the area of radiological science was titled "Development of an Improved Neutron Computed Tomography System Utilizing a Cooled Charge Coupled Device Array."

Wellesley College named Mr. Sorci the winner of the Virginia Wainwright Sonnet Prize.

GRADUATE ENROLLMENT, HONORS, AND AWARDS

During the academic year 1989-90, approximately 150 students were enrolled in our graduate program. Of this number, 30 students entered the program in fall and 6 students enrolled in spring. The department granted 48 advanced degrees this past year; they included 19 doctoral, 5 engineer/master, 21 master, 3 five-year bachelor/master degrees.

The MIT Student Chapter of the ANS received second place honors for the 1988-89 Samuel Glasstone Award. This is a monetary award given to a student chapter that has notable achievements in public service and in the advancement of nuclear science and engineering. Brian Aviles, Stephen Boerigter, and Michael Houts shared this prize because of their outstanding support of chapter activities during the 1988-89 academic year.

Tony Hechanova was selected by the ANS Scholarship Subcommittee to receive an ANS Graduate Scholarship Award, which he received at the ANS Annual Meeting in June 1990. Tony also received an award for the best paper in the thermal hydraulics area at the ANS Student Conference that was held at Penn State in April. Kimberly Credit, an incoming graduate student from the University of Lowell, received the ANS John and Muriel Landis Scholarship Award at the annual meeting.

Department fellowships for the coming year were announced at the April student/faculty dinner meeting. The Manson Benedict Fellowship for 1990-91 will go to Steve Boerigter. The Theos Thompson Memorial Fellowship will support Robert Jacquemin during the fall semester 1990, and Riccardo Betti during the spring term 1991.

The Sherman Knapp Scholarship for 1989-90 was offered to James Fox. Without the continuing generosity of Northeast Utilities, the department would be unable to offer this award.

The Institute of Nuclear Power Operations (INPO) granted the department two graduate fellowships for the academic year 1989-90. Christopher Steele and Jonathan Witter were chosen to receive the INPO awards based on their academic standing and field of interest.

Department of Energy (DOE) Fellowships for 1989-90 were awarded to eight graduate students. Daniel Lo and Justin Schwartz received DOE Magnetic Fusion Energy Technology Fellowships. Nuclear Engineering and Health Physics Fellowships were awarded to Vinh Dang, Tom DeLorey, Jess Gehin, and Jerry Martin. William Hollaway and Katherine Yuracko were supported with Radioactive Waste Management Fellowships. The DOE recently announced that two incoming graduate students will receive a DOE Fellowship for the coming year; they are Christine Della Penna and Kenneth Crosswait.

The Health Physics Society awarded a fellowship to Leigh Scott Johnson for the coming year. Mr. Johnson completed a master's degree in health physics this spring. Through contacts with Schlumberger-Doll Research, a fellowship in Radiation Science and Technology will be established to support the graduate training of a PhD student. The first fellowship, to begin in September 1990, will be awarded to David Cist who has an interest in computational aspects of image processing.

Student Organizations

The ANS Student Chapter continued its efforts to fortify the department during the past year. In conjunction with the Institute's Orientation Period, the ANS organized

orientation sessions for newly admitted graduate students. They scheduled a full lineup of Monday afternoon guest lecturers so that a different aspect of research was covered every week. They also sponsored "fun" activities such as various sport teams, two steak fries, monthly student-faculty dinners, and the annual holiday party.

Alpha Nu Sigma, the national honor society for nuclear science and engineering, had a productive year. Last October it co-sponsored the second David J. Rose Lecture in Nuclear Technology given by Dr. Hans Blix, Director General of the International Atomic Energy Agency. An enthusiastic audience enjoyed his presentation on the subject "World's Energy Needs and the Nuclear Power Option". In addition, the members updated two guidebooks that are beneficial for both incoming and current students. The first is a question and answer booklet regarding department facilities, etc.; the second is a guidebook to the Institute's nuclear science and engineering literature collection.

RESEARCH ACTIVITIES

There are four basic areas of research within the Department of Nuclear Engineering. They are Fission, Fusion, Radiation Science and Technology, and Energy Policy and Economics. The following paragraphs will attempt to catalogue research activities currently underway.

Fission

The department's efforts on advanced reactors have expanded to include vigorous activities in public communications and policy studies concerning advanced nuclear power technologies. Relevant articles which have appeared in the past year include "Advanced Light Water Reactors," by Professors Michael Golay and Neil Todreas in Scientific American; and commentaries by President Paul Gray lauding the gas-reactor related work of Professor Lidsky particularly, and prospects for advanced reactors generally, in the Wall Street Journal and in an issue of Popular Science focusing upon nuclear power.

In expanding the department's efforts in public communication, Professor Golay has begun organizing the first MIT International Conference on the Next Generation of Nuclear Power Technology to be held at the Institute next October. The purpose of this conference, the first of a series, is to stimulate a process on consensus-building, for which a long period of reflection is thought to be necessary.

The department's efforts in the area of advanced reactor research can be organized as follows: Light Water Reactors (LWR), Modular Gas-Cooled Reactors (MHTGR), Liquid Metal-Cooled Reactors (LMR), and Advanced Instrumentation and Control.

In the area of LWRs, Professor Golay has continued his research on system simplification and its implications for avoiding errors by nuclear power plant operators, particularly in responding to unexpected transients. Professors Golay and Mujid Kazimi have continued their collaborative investigation on the role of non-condensable gases in affecting the rate of condensing heat transfer under conditions applicable to accidents within light water reactor containment buildings.

In the area of MHTGRs, Professors Lanning and Lidsky continued studies of a direct Brayton cycle turbine power plant based on the passively safe MHTGR core. This study has been widely circulated and has attracted considerable attention. The development of a complete dynamic model and an analysis of a candidate control system has been completed. The DOE has expressed willingness to fund a much larger scale "industrial strength" design study and preparations on this effort have been initiated. Under the supervision of Professors Driscoll and Todreas, numerical and analytical work to improve passive decay heat removal by natural convection and advanced reactors such as the MHTGR is continuing.

The main research regarding LMRs being pursued within the department concerns the pros and cons of using the Integral Fast Reactor (IFR) for transmutation of long-lived nuclear

waste species into short-lived forms. If this can be done successfully, a new degree of freedom could be added to national efforts to dispose of nuclear wastes. The need for terrestrial waste disposal would not be eliminated by this initiative, but might be reduced. This work involves Dr. Marvin Miller and Professors Golay and Lidsky.

In the area of advanced instrumentation and control, Professors Henry, Lanning, and Meyer, and Dr. Bernard (of the NRL), along with a group of six to eight students, have been studying the application of fault-tolerant digital systems for instrumentation and automatic control of nuclear power plants. These studies involve research in modelling systems for real-time calculations involved in the control algorithms, as well as simulation and actual reactor demonstration of the fault tolerant concepts for fully automatic control of reactors. The studies include control of small reactor systems such as space power reactors and small power reactors combined into multi-modular power reactor systems. Studies are also being made on control of LWR cores where multi-dimensional effects must be included. A fast running coupled neutronics and thermal hydraulics nodal code has now been made operational. In particular, a previous PWR system model and controller were extended to cases of significant burnup; in addition, a model was developed for a particle bed hydrogen cooled reactor for space applications. Experiments have been carried out both at the MIT Reactor (MITR) and with a small reactor at the Sandia National Laboratory in which the unique controller is demonstrated to safely raise the power at a desired rate of change and reach the desired value without overshoot.

In-pile loop research into means to achieve dose and corrosion reduction continues at the MITR under the direction of Professors Otto Harling and Driscoll. During the year a series of in-pile experiments were completed on the PWR loop which now operates routinely. These experiments have determined the influence of pH or boron to lithium ratio on the radioactive corrosion product buildup in PWRs. A new BWR loop was completed under this project. This loop will be used for important radiation chemistry experiments.

The department, in cooperation with the Energy Laboratory and the Center for Energy Policy Research, inaugurated a major program on nuclear safety research in the spring. The program, entitled "The MIT International Program on Enhanced Nuclear Safety," is aimed at reducing risks of accidents in existing nuclear plants. Research will focus upon improved technology for service and maintenance of plants, and on the organization and management of such plants. Participants include Professors Hansen, Lanning, Lidsky, McFarland, Meyer, Rasmussen, and Siu, and Dr. Richard Lanza.

In the area of reactor physics modeling, Professor Henry and his students are engaged in efforts concerned primarily with the fast, accurate prediction of reactor transient behavior. Validation of the standard two-group model by comparison with multigroup, reference calculations has shown no need to introduce extra refinement in applying it to transient analysis of pressurized water reactors. A very fast, transient nodal synthesis method for reconstructing time-dependent flux behavior from core instrument readings has been developed, and preliminary tests are very encouraging. Finally, a nodal code for analyzing static flux shapes for cores composed of hexagonal fuel assemblies (such as the new production reactor and gas-cooled, graphite-moderated power reactors) has been specified, programmed, and tested.

Study in the area of reactor safety, reliability analysis, and risk assessment is conducted by Professors Norman Rasmussen and Siu. Professor Siu continued to work on the development of methods to treat the impact of dynamically changing process variables on plant risk. Two approaches, involving dynamic event trees and discrete event simulation models, are being pursued. A project to model the behavior of the plant operator crew during an accident sequence, which complements the above work, is also continuing. Professors Rasmussen and Siu have also initiated a new project, under the sponsorship of a local utility; this project is aimed at determining the risk impact associated with various regulatory activities.

Efforts in the area of thermal hydraulics and fluid flow have continued by Professors Golay, Kazimi, and Todreas. Topics such as single-phase multiple channel behavior under decay heat conditions, mixed convection in vertical flow channels, flow distribution and heat convection mechanisms in bare and wire-wrapped bundles, analysis of heat transfer and hydraulics of two-phase flow, and advanced computational methods for single and two-phase flows are under investigation.

Departmental research in the large-scale, MIT-Idaho National Engineering Laboratory Engineering Research Program was completed in the fall semester. The work related to application of electronic simulation of reactor problems. Models of both BWR and PWR plants were successfully demonstrated. This work was under the direction of Professor Hansen with the participation of Dr. Eduardo Depiante.

Fusion

Fusion research is conducted at the Plasma Fusion Center. NED faculty affiliated with this center include Professors Freidberg, Ian Hutchinson, Kazimi, and Kim Molvig. Professor Freidberg and Dr. Simo Hakkarainen (a former graduate student, now an Alcator staff member) developed an ultra-fast numerical technique for reconstructing the shape of the plasma cross section in a tokamak from external magnetic data. The procedure is being implemented on the Alcator C-Mod experiment. Dr. Dan Cohn and Professor Freidberg have been investigating various methods of burn control in ignited tokamaks. They have suggested auxiliary power feedback as the most desirable procedure, and this recommendation has been accepted by both the Compact Ignition Tokamak (CIT) and International Thermonuclear Experimental Reactor (ITER) design groups.

Professor Hutchinson continues to lead the Alcator group, as Division Head in the PFC. Construction of the new Alcator C-Mod tokamak experiment is proceeding well and first plasmas are expected in early 1991. Approximately 16 graduate students have research assistantships with this group and thus have the opportunity to work on a world class confinement experiment as part of their educational experience.

Professor Kazimi's interest in the area of fusion safety focuses on the implications of thermal transient behavior of various blanket designs, the chemical kinetics of lithium fires, and of magnetic transients. During the past year he and his students concluded the investigation of the consequences of introducing neutron absorbers in the shield/blanket area for reduced activation. They also initiated a study of the radioactive waste management implications for fusion reactor designs. Professor Mohamad Abdou of UCLA spent one month of his sabbatical leave working with them.

Professor Molvig's research was devoted to developing algorithms in logic that yield hydrodynamic behavior which will ultimately provide schemes for massively parallel computers and enhance their capabilities. With his students, he has worked out the theory and has carried out code development to develop the range of validity of the model.

Radiation Science and Technology

The radiation science and technology (RST) area includes research in applied radiation physics, condensed matter science and molecular simulation, radiological sciences, and radiation health physics. Professor Yip continues his investigation of fundamental materials properties and behavior through atomistic simulations. Professor James Dufty from the University of Florida spent a sabbatical semester working with Professor Yip on theoretical problems of liquid to glass transition. Also visiting the department during the semester and joining in this research was Dr. R. Schmitz from the University of Munich, West Germany.

Research in the area of nuclear materials and radiation effects continues to expand. Professor Kenneth Russell has made major progress in theoretical and experimental

investigation of wetting of ceramic fibers by metallic melts. He has also developed a model for circuit substrates.

Professor Sow-Hsin Chen and doctoral student Xuan-Hui Guo have discovered by small angle neutron scattering the new structure of a protein-surfactant complex in solution. The complex has a structure similar to a flexible polymer in solution except that the surfactant molecules SDS form micelle-like clusters along the backbone of the denatured polypeptide chain. This structure is significantly different from the traditionally believed structure of the complex and has practical application in the protein-SDS gel electrophoresis technique for determination of the molecular weight of the protein.

Professors Gordon Brownell and Yanch have begun a three year DOE-funded project to develop an accelerator source of epithermal neutrons for neutron capture therapy. The accelerator will be built by Science Research Laboratory in Somerville while the moderator, reflector, filtering, and shielding will be designed using simulation methods by Professors Brownell and Yanch in the Whitaker College Biomedical Imaging Laboratory.

Professor Yanch has begun a dosimetric study of the use of reactor-produced beta-emitters in the treatment of rheumatoid arthritis. This work has been funded for an initial one-year period by the Whitaker Health Sciences Fund. Another project involves the use of computer simulation in single photon emission computed tomography. Experimental verification of Monte Carlo generated results has been set up with the New England Medical Center (NEMC). Along with co-workers at the NEMC and the University of Kentucky, Professor Yanch is investigating the use of californium implants for treatment of brain tumors.

Energy Economics and Policy

In the area of energy economics and policy, Professor Rasmussen and his student, Katherine Yuracko, with the help of Professor Gordon Kaufman of MIT and Professor Howard Raiffa of Harvard, completed a study proposing a methodology for reaching decisions among adversaries. As an example, the methodology was applied to the problem of the transportation of spent nuclear fuel. Dr. Yuracko has accepted a position on the President's Science Advisor's staff where we hope she will be able to apply this technique to important national problems.

With support from the Rockefeller Brothers and Ploughshares Funds and the Prospect Hill and W. Alton Jones Foundations, Dr. Miller initiated a research project on reducing the threat of nuclear weapons in the Middle East. He is collaborating with Dr. Avner Cohen of Tel-Aviv University.

Studies in the area of space nuclear power systems have continued. Professor Lanning is working with a graduate student and one or two UROP students on the assessment of possible nuclear power systems for deployment in stations such as a lunar station. One specific reactor under assessment is the Space-Thermionic Advanced Reactor Compact called the STAR-C reactor. Possible design concept studies and reactor control studies have been initiated. Professor Lanning is a member of the steering committee for the NASA-supported MIT Space Grant Program. This program encourages education for space engineering students through continuing fellowships.

FACULTY

Faculty Service to the Institute

Professor Lidsky served on the Ad Hoc Faculty Advisory Committee to the Corporation Committee on the Presidency. In addition to serving as departmental representative of the CGSP, Professor Henry held membership on the Institute's Advisory Committee on Shareholder Responsibility. Professor Molvig was a member of the Faculty Club Advisory Board.

Professor Rasmussen chaired the Committee on Reactor Safeguard. Professors Harling, Ballinger, Lanning and Kazimi also participated on this Committee. Professor Kazimi served on the Committee on the Center for Materials Science and Engineering. Professor Todreas chaired the Committee on Radiation Exposure to Human Subjects. Professor Brownell also served on this Committee. Professors Rasmussen and Todreas were both members of the Institute Council on Environmental Health and Safety.

Professor Elias Gyftopoulos continued his services as chairman of the MIT Sustaining Fellows Program, and as a member of the advisory committee of the Center for Advanced Engineering Study. He was also appointed as a member of the faculty advisory group of the Center of Technology, Policy, and Industrial Development and participated in the preparation of the proposal of the Engineering Coalition of Schools for Excellence in Education and Leadership. Professor Richard Lester continues to serve on the Program Board of the Center for Energy Policy Research and the faculty advisory board of the Center for Technology, Policy, and Industrial Development, and has been appointed to serve on an ad hoc MIT faculty study group to address the international relationships of MIT. Professor Meyer is a member of the School of Engineering Committee on Educational Programs.

Faculty Activities and Accomplishments

In this portion of the report highlights of national and international faculty activities of the past year are presented.

Professor Brownell was one of the founders of a new society, "Medical Imaging," jointly sponsored by the IEEE. He also participated in international conferences in Amsterdam and Paris on NMR imaging and nuclear medicine.

Professor Chen served as a member of the program review committee of the Intense Pulse Neutron Source (IPNS) operating at both Argonne and Los Alamos National Laboratories. Due to the safety-related shutdown of both Brookhaven and Oak Ridge high flux reactors, there is a critical shortage of neutron beam time at all small angle scattering facilities in the nation. Professor Chen proposed to the DOE Basic Energy Sciences Division to build an additional small angle neutron scattering spectrometer at IPNS. The proposal has been approved and construction of the spectrometer will begin in September.

Professor Freidberg and graduate students Tom Hsu and John Urbahn were active participants in the recent PFC high school outreach program. They gave lectures, demonstrations, and tours to a group of about 80 high school students and teachers from the Boston area.

Professor Golay spoke before the House Interior and Insular Affairs Committee's Energy and Environmental Subcommittee on the prospects for advanced reactor technologies.

In October 1989, Professor Gyftopoulos was the keynote speaker in a European community conference on cogeneration held in Madrid, Spain. In January 1990, he was invited to a conference on Science, Technology, and the Environment, organized by the United Nations, and held in Athens, Greece. Professor Elias Gyftopoulos and Gian Paolo Beretta coauthored a text on "Thermodynamics: Foundations and Applications," which is scheduled for August publication by Macmillan Publishing Company.

Professor Hansen chaired an NSF-sponsored study of the Japanese nuclear industry. The study was part of the foundations JTEC (Japanese Technology Evaluation Center) program. It involved a detailed review of many aspects of the Japanese industry, and the related R&D activities in Japan.

Professor Henry presented a week-long series of lectures at the Politecnio di Torino on modern methods for analysis of light water reactors. He also gave a day of lectures on this same subject to a group of reactor physicists at Electricite de France. He was one of the invited speakers at the Plenary Session of the International Conference on the

Physics of Reactors held in Marseille. Along with Dr. Henry Honeck, a graduate of the department, Professor Henry presented a two-week course at the Savannah River Laboratory on modern reactor physics design methods for the light and heavy water moderated reactors. A one-week reduced version of the course was then given at Los Alamos.

Professor Harling was invited to participate as an organizer of the new International Group on Research Reactors. He presented two invited papers at the first meeting of this group in February 1990.

Professor Hutchinson was a keynote speaker at the April 1990 Conference of the Association for Religion and Intellectual Life and presented a paper entitled "Faith's Failure of Nerve." Last October, he presented an invited paper about Alcator C-Mod at the IEEE 13th Symposium on Fusion Engineering. He also appeared before the Fusion Policy Advisory Committee, a high level review panel for DOE to describe MIT's research.

Professor Kazimi serves as the chairman of the Severe Accident Steering Committee for the New Production Reactor Project at Argonne National Laboratory. He is also a member of the University of Chicago special review committee of the ANL Liquid Metal Reactor Safety R&D program. Both he and Professor Siu presented a special summer short course on the methodology of nuclear power plant risk assessment called Individual Plant Evaluation. Approximately 25 people attended from utilities, engineering firms, and government agencies. Professors Kazimi and Todreas authored a new textbook entitled *Nuclear Systems: Thermal-Hydraulic Fundamentals* which appeared in January 1990. A second volume entitled *Nuclear Systems: Elements of Thermal Design* will appear in August 1990.

Since publication of the MIT Commission on Industrial Productivity's final report, *Made in America: Regaining the Productive Edge* in May 1989, Professor Lester and his colleagues have been invited to give over one hundred presentations of the Commission's findings to industrial, government, and academic groups in the United States, Japan, Europe, and Mexico. The Commission's report has been published in Japan and in the Republic of Korea. In addition, he continues to serve on the Radioactive Waste Management Board of the National Academy of Sciences.

Professor Lanning has been invited to co-chair a panel supported by the National Science Foundation to analyze and compare European and US technologies in the area of advanced instrumentation and controls for nuclear power plants. He continues to serve on the Safety Audit Committee at Northern States Power Company.

Professor Lidsky's work on the direct-Brayton cycle nuclear reactor has continued to attract attention. In the last year he has given invited papers on the subject at Argonne and Oak Ridge National Laboratories, Lincoln Laboratory, and the Woods Hole Research Institute. He also took the pro-nuclear side in a National Public Radio debate concerning responses to the problem of greenhouse gases.

Dr. Miller gave an invited paper on nuclear-powered attack submarines and the proliferation of nuclear weapons at a Conference on Latin American Nuclear Cooperation that was held in Montevideo, Uruguay, last October. In March, he made a presentation on the proliferation implications of advanced nuclear reactors to the National Research Council's Committee on Future Nuclear Power Development.

Throughout the summer and early fall, Professor Molvig was called upon to present his views on "Fusion Program Strategy" - an aftermath of his chairmanship of the DOE Magnetic Fusion Advisory Committee Panel 22. In October, he appeared before the Subcommittee on Investigation and Oversight of the US House of Representatives Committee on Science, Space, and Technology. Last April, he appeared before the Fusion Policy Advisory Committee.

Professor Rasmussen continued to serve on the Presidential Commission on Catastrophic Nuclear Accidents. He was also a member of the Review Committee on Savannah River PRA; of the Visiting Committee for the Department of Nuclear Energy at Brookhaven National Laboratory; and of the Visiting Committee at Princeton Plasma Physics Laboratory. During the year he became a member of the Committee on Film Badge Dosimetry in Atmospheric Nuclear Tests for the National Research Council; of the Review Committee for NUREG 1150 (Nuclear Regulatory Commission); and of the Task Force for Strategic Defense Initiative Office for the Defense Science Board.

Professor Russell continues to serve on the American Society for Metals' Awards and Honors Committee, and is a member of the ASTM Committee E-10 on Radiation Effects. He also chaired the Ferrous Metallurgy Committee of the AIME. He edited a book of Physical Metallurgy of Controlled Expansion Invar-Type Alloys, just published by TMS.

Professor Siu joined the Technical Program Committee for the Nuclear Reactor Safety Division of the ANS. He chaired a session at the annual meeting of the Society for Risk Analysis, and participated in two NRC workshops on severe accidents and organizational factors.

Professor Todreas (and Professor Rasmussen) once again presented their two-week summer course entitled, "Nuclear Power Reactor Safety" during July 1989. Outside activities include chairing the Nuclear Safety Research Review Committee of the NRC and serving on the ANL review committee of the Reactor Analysis and Safety Division. During the year he was appointed to the Advisory Council of INPO; to the National Academy of Sciences Committee on Future Nuclear Power Development; and to the BNL Department of Nuclear Engineering Visiting Committee.

Professor Yip was invited by the Atomic Energy Council, Republic of China, to visit and discuss problems of nuclear waste management with their radioactive waste administration.

Faculty Honors and Awards

The National Science Foundation selected Professor McFarland as a 1990 Presidential Young Investigator. This award recognizes Professor McFarland's research and teaching accomplishments and his potential as a leader in the academic community.

Professor Lidsky was awarded the Metcalfe Professorship (Metcalfe Professor of Engineering and the Liberal Arts). He and Professor M.R. Smith of the School of Humanities will share the chair, the title of Professor of Engineering and the Liberal Arts, and the task of guiding the Institute's Context Program. Professors Lidsky and Smith have instituted the Context Support Office and a number of continuing Context-related activities.

Professor Yanch is the first recipient of the Class of 1958 Assistant Professorship Chair. She will hold this chair for three years, 1989-1992.

The Student Chapter of the ANS named Professor Rasmussen as the Outstanding Teacher for the academic year 1989-90. He also received the "Distinguished Contribution Award" from the Society for Risk Analysis.

The MIT Commission on Industrial Productivity, of which Professor Lester was Executive Director, was awarded the Special Prize of the Ohira Memorial Foundation of Japan for its book, *Made in America*.

Department of Ocean Engineering

INTRODUCTION

This was a year of growth and progress in many respects for the Department of Ocean Engineering. For example,

- o The first of a pair of new undergraduate subjects on ocean science and technology was given, offering MIT undergraduates a new format for learning about ocean problems and challenges. (See UNDERGRADUATE EDUCATION below).
- o The volume of research in the Department increased by more than one-third this year, following a similar increase last year. This growth was distributed over several of the areas in which the Department is active, not concentrated in any single one. See the section on RESEARCH below for a description of some major activities and accomplishments.
- o A much larger part of the Department's research effort than ever before was devoted to experimental projects. The old towing tank was completely renovated for use in ocean engineering and technology.
- o Three faculty members, the first ever in the Department, were appointed to endowed chairs. One, the William I. Koch Chair, is exclusively an Ocean Engineering chair. The others, the Kawasaki Chair and the Weber-Shaughness Chair, are School and Institute chairs, respectively.

In other respects, the Department performed well, but less dramatically. Enrollments continued at the levels of recent years; at the undergraduate level, the number is still too small, but the number and quality of graduate students remain high. Modest improvements have been made in all of our education programs. The faculty remains committed to the highest standards of professional activities, including a wide range of Institute and public-service activities.

UNDERGRADUATE EDUCATION

The Department offered the first term of a new two-term subject, Introduction to Ocean Science and Technology, in the spring term. The objective in developing this subject was to enable a broad cross-section of MIT undergraduates to obtain some fundamental knowledge of the field and, more generally, to learn of the challenges and opportunities in studying, using, and protecting the oceans. Professor Jerome H. Milgram organized the course, incorporating three technical modules (oceanography, acoustics, and wave/body dynamics) and a case study. A follow-on subject, first to be offered next year, will involve the students in the planning, conduct, and analysis of an experiment at sea. Prerequisites were specified in such a way that sophomores in several departments would automatically be qualified to register, and so they could learn about ocean engineering without having to commit themselves to a major in it. The first-term subject carries credit toward the general Institute requirement for science-distribution subjects, and the second term provides partial satisfaction of the laboratory requirement.

Professor Milgram was joined in this undertaking by Professor Ira Dyer, who taught the acoustics module, Dr. Wayne R. Geyer of the Woods Hole Oceanographic Institution, who taught the oceanography module, and Professor Judith T. Kildow, who prepared and led discussions of the case study.

GRADUATE EDUCATION

Professor Kildow developed a new subject, Introduction to Policy Analysis, offered jointly by the Ocean Engineering Department and the Technology and Policy Program (TPP), for the purpose of introducing engineering students to the concepts and methods of policy analysis. Thirty students registered for this first time. Eventually, it could serve an important need across the entire School of Engineering.

Professor Koichi Masubuchi has, in collaboration with the MIT Center for Advanced Engineering Study, prepared a series of 20 videotaped lectures, entitled Analysis of Welded Structures. These constitute the most comprehensive course of instruction ever available anywhere on this subject. Course materials include videotaped lectures in either English or Japanese, course manuals, and Professor Masubuchi's landmark reference work of the same title.

Assistant Professor Nicholas M. Patrikalakis has been collaborating with Professor David C. Gossard, Mechanical Engineering Department, to offer new interdepartmental subjects on the design and implementation of computer-aided engineering systems. Professor Patrikalakis has taken the lead in the area of computational geometry.

Course XIII-A, Naval Construction and Engineering, has added a requirement that all students take at least one subject in the area of manufacturing technology, and this area is now also available to three-year XIII-A students as an area of concentration.

STUDENT PROJECTS

Oar Design: The project on oar development, first reported last year, continues with the unabated enthusiasm of the students involved, all of whom are active in MIT rowing. It is almost entirely an undergraduate effort, with students coming from many departments -- but not from Course XIII. The project is being directed by Professors A. Douglas Carmichael and Justin A. Kerwin and Associate Professor Paul D. Sclavounos. Comparisons are being made between this project and the Institute's so-called Pratt project, which, in the 1970s, revolutionized the sport of sailing, through both improved design and the more rational organization/management of competition. There is a major difference between the two projects,

however, in that the Pratt project was well-funded, and the current one is not. But the oar-design project is nevertheless serving a valuable educational purpose, giving students an opportunity to solve some very applied problems that require, in the process, the development of fundamental new knowledge.

FACILITIES

Ocean Engineering Test Facility: Under the supervision of Associate Professor Michael S. Triantafyllou, the former towing tank has been completely renovated for use as a modern ocean engineering test facility. A new carriage, running on rollers and providing a very smooth ride, was designed and built. It is capable of supporting oscillating machinery for use in testing, for example, vibrating cylinders and foils. A new drive motor was installed, and a new data acquisition system is being built, as is a computer-driven wave maker. A new beach is also being installed.

As this description implies, the test facility can still be used for testing ship models for educational purposes. It can now also handle a range of ocean engineering projects for both education and research, and Professor Triantafyllou has already undertaken some fundamental experiments to elucidate some observed phenomena in the vibration of large cable structures, for example, the large observed damping, drop in drag coefficient, and low-frequency drifting involved in the beating response (low-frequency modulation of the strumming motion) of cables in a crossflow. See also the description below (under RESEARCH) of another project of Professor Triantafyllou's.

Other Laboratories: The Department continues to develop the Ocean Engineering Design Laboratory (under Professor Chryssostomos Chryssostomidis), the Variable Pressure Water Tunnel (under Professor Kerwin), and the Welding Systems Laboratory (under Professor Masubuchi). Professor Milgram's Marine Hydrodynamics and Instrumentation Laboratory will be moved to new quarters in the coming year; it is being used more and more for the development of equipment and instruments for experiments at sea (see description of recent accomplishments below under RESEARCH). It will also be the focus of undergraduate activities related to the new undergraduate subjects (described above under UNDERGRADUATE EDUCATION).

RESEARCH

Ocean Acoustics: The Department's long-running program in Arctic acoustics is being scaled down, partly because of changes in funding patterns, partly because the relevant faculty members have decided to pursue new challenges. As a part of this shift, we have started a new program of research on the backscattering of acoustic waves from the sea-surface zone under conditions in which breaking waves occur.

High-performance sonar systems operating in a fairly low-frequency range (a few hundred Hz) have been shown to be limited by acoustic backscattering when the sea surface is rough, especially if wind speed exceeds about 25 knots. Neither theoretical models nor carefully controlled experiments are available to explain such backscattering. The leading hypotheses for the phenomenon are (a) macrobubble plumes injected by wavebreaking, (b) deep microbubble curtains that are convected to considerable depth by various mechanisms, and (c) very-high-slope facets of the sea surface. Theoretical, laboratory, and at-sea experiments will be conducted to clarify the phenomenon and its cause. Professor Dyer has been acting as chief scientist for a large program in this area, involving several institutions, and MIT has major specific responsibilities for the at-sea experiments. Other faculty members with key roles in this program are Professor Arthur B. Baggeroer and Associate Professor Henrik Schmidt.

Propulsor Performance: Professor Justin E. Kerwin continues to direct one of the most extensive research programs in the Department, historically focused on the design of propulsors for surface ships, but now broadened to encompass propulsors for submarines, control systems for unmanned submersibles, and more general fluid-flow problems. In all research conducted in Professor Kerwin's laboratory, the Variable Pressure Water Tunnel, a distinguishing characteristic is the way in which analytical and numerical modeling are combined with meticulous experimental verification, whether the purpose be to determine some fundamental property in fluid mechanics or to develop a design code.

Fundamental problems studied in the laboratory include unsteady propeller cavitation (for which Dr. Spyros Kinnas, Research Engineer, is the principal investigator), measurements of the flow field around a submarine-like body undergoing large-angle "coning" motions, vortices generated at the junction of two bodies, and the flow-field effects of body surfaces with compound curvature. State-of-the-art design codes produced in the laboratory include (a) a new propeller unsteady-force program (PUF-5) that robustly tracks the vortex-wake geometry of a propeller in unsteady flow and predicts propeller transverse forces on a maneuvering underwater vehicle, (b) a program (DPSF-2) for designing ducted propellers for the propulsion and control of unmanned underwater vehicles, and (c) a lifting-line program (PLL) that handles an extremely wide range of marine propeller forms. The last of these was used to design the propeller for the MIT human-powered submarine, for which it produced an optimum form that looks more like an airplane propeller than the stubby, highly skewed forms that are so common among marine propellers. Work is continuing with DPSF-2 to develop controllable-pitch stators that will make it possible to change propeller thrust almost instantaneously. Since marine propellers have complex sculptured shapes, first steps have been taken to integrate design-code development with the geometric modeling advances being made in the Ocean Engineering Design Laboratory (see following item).

Geometric Modeling: Professor Patrikalakis and Professor Chryssostomidis are developing a general geometric modeling system for the Navy, called Praxitelis, which provides state-of-the-art capabilities in accurate data exchange, high-accuracy shape approximation, advanced shape interrogation, and automated inspection. The system integrates many aspects of their fundamental research in this area, which was initially focused on the problems of defining surface intersections robustly and automatically. The analysis of intersections remains fundamental to this work, but it led them naturally into related issues, an important one being shape approximation, which is critical to all processes of electronic data exchange. In the future, their geometric modeling techniques will be essential in a program to improve manufacturing capabilities, especially in the modeling and simulation of the manufacturing processes for complex marine structures, and they are already collaborating in this area with faculty in the Departments of Mechanical Engineering and Materials Science and Engineering.

Sailing Dynamometer: Over the last several years, Professor Milgram developed a unique sail-force dynamometer for measuring the total force of a yacht sail on the hull. Complete data were obtained for two sailplan geometries, and, with these data, Professor Milgram was able to develop new mathematical sail-force models for use in velocity prediction programs. During the same period, a graduate student, Andreas Klein, developed a computer-interfaced video camera for measuring actual sail shapes under load. His shape determinations are finished, and the results have been used to make aerodynamic predictions of sail forces for comparison with the measured total forces. Unfortunately, the sail test boat (the dynamometer) was subsequently completely wrecked in a boatyard accident, but a large and unique body of data had been accumulated before this happened.

Large-Amplitude, Low-Frequency Motions of Ocean Platforms: Although it has been recognized for at least 20 years that moored ocean platforms are often subject to very-low-frequency hydrodynamic loads that cause resonance with their typically soft mooring systems, there are still major gaps in the offshore industry's ability to design platforms that can avoid or cope with this phenomenon. Its general nature is certainly well understood, but a quantitative analysis requires the solution of a very complex hydrodynamics problem, so daunting that all existing design codes are built on simplified models, the validity of which is uncertain.

Such problems naturally attract attention at MIT, and so it is hardly surprising to find that Professor J. Nicholas Newman, Associate Professors Paul D. Sclavounos and Dick K.-P. Yue, and Dr. F. Thomas Korsmeyer, Research Engineer, are all devoting a substantial part of their research effort to this. Collectively, they are approaching the problem from several complementary directions, including (a) rigorous and complete solution of the pertinent second-order problem, (b) direct solution of the full nonlinear problem, and (c) new numerical methods. Under (c), one approach is especially notable for its potential fundamental importance to numerical analysis: Professor Yue and Dr. Korsmeyer, with support from the National Science Foundation, are investigating the use of so-called "O(N)" solvers,* which offer the possibility of order-of-magnitude reductions in computation time.

Recently, Professor Sclavounos has attacked yet another aspect of the problem, analyzing the statistics of second-order platform motions. The motion of a ship in waves, for design and operations purposes, is typically described statistically, since the ocean waves themselves can only be handled in such a way. But the ship-motion problem is primarily a linear one, for which classical statistical methods suffice. The same is not true of the nonlinear (second-order) low-frequency moored-platform problem. Professor Sclavounos is breaking new ground here.

Splashdown and Towing of the Space Shuttle's Solid-Rocket Booster: Professor Milgram, Professor Yue, Dr. Korsmeyer, and Dr. Fernando Frimm (Postdoctoral Associate) undertook an analysis of the dynamics of the solid-rocket booster (SRB) after it has served its primary purpose in helping the space shuttle achieve orbit. NASA recovers the SRBs after launch and re-uses them, but damage has sometimes been observed that might be attributed to loads incurred during water impact or towback to shore. The MIT analysis provided NASA with estimates of the loads that must be allowed for.

Short Waves in a Ship Wake: Professor Milgram and Dr. Frimm successfully measured the short-wave spectra inside and outside of the wakes of several ships in ocean trials. The experimental data included real and synthetic-aperture radar (SAR) images, as well as the MIT measurements, which provided "ground truth" for the radar data. Professor Milgram and a graduate student also conducted experiments at The University of Michigan, successfully measuring the dissipation of waves by turbulence. They showed that the rate of dissipation is consistent with the hypothesis that the principal mechanism is the downward convection of wave energy by the turbulence velocities. Professor Milgram also demonstrated that the combination of surfactant redistribution and wake turbulence plays a major role in causing dark centerline SAR images of ship wakes that have often been observed. Such phenomena are crucial in understanding and analyzing the long-lived ship tracks that frequently appear on SAR and visual images of the ocean surface.

Flapping Propulsors: Many fish propel themselves by flapping their tails, and they do it very efficiently indeed, achieving very high speeds. Professor Triantafyllou is conducting experiments and analysis to explain how fish swim so efficiently and determine whether such a method of propulsion might be usable in underwater vehicles. Recent advances in wake dynamics allowed him to show that thrust is produced through the development of a reverse (in direction of rotation) Karman street, which creates a jet-like average flow behind the fish. Such a flow has a preferred frequency for maximum spatial amplification, hence defining a frequency and amplitude for large thrust development. Fish, of course, have learned through evolution to optimize this mode of propulsion. Now Professor Triantafyllou has shown how, at least in principle, man might adapt this mode of propulsion to underwater vehicles.

Reduction of Residual Stresses and Distortion in Weldments: Professor Masubuchi is internationally recognized for his contributions to the analysis of welded structures. Recently he has focused on the development of procedures for reducing residual stresses and distortion caused by welding, with emphasis on doing this in real time, i.e., during the actual welding process, when incompatible (nonelastic) strains are being created. This requires, at a minimum, that techniques be available for analyzing the phenomena involved, but it really becomes feasible only if additional capabilities are available for sensing what is happening during welding and for making the necessary process changes. Professor Masubuchi and his students have conducted many experiments to determine what kind of ameliorative actions might be effective for this purpose. They have demonstrated that it is possible to reduce residual stresses in weldments in high-strength steels (e.g., HY-130) by actively altering thermal patterns during welding. The application of such a technique could help prevent the stress-corrosion cracking that is a major current problem in HY-130 weldments.

*When a set of N linear equations is solved by elementary methods, the computing time varies as N^3 , which is referred to mathematically as being "of the order of N^3 " or $O(N^3)$. More sophisticated (iterative) methods require a time that is $O(N^2)$ (i.e. computing time varies as N^2), a critical improvement if N is very large. The new method, the $O(N)$ method, would require computing time that varies simply as N , a tremendous further time reduction in cases of large N , which, for ocean-platform problems, is typically in the thousands.

Dynamics of Drill Strings: Professor J. Kim Vandiver has been supported by a consortium of 12 companies (6 US, 6 foreign) in a program of research on the vibration of drill strings. The objective is to reduce expensive down time that results from excessive dynamic bending and whirling motions.

Design of Structures for Large Energy Absorption: For some years, Professor Tomasz Wierzbicki has been investigating the mechanisms by which thin-walled structures fail plastically when they are loaded suddenly and catastrophically. Now some of his predictions can be produced on a PC through the use of new software, CRASH-CAD, that Professor Wierzbicki has developed with Dr. W. Abramowicz; it can calculate the energy absorption and mean crushing strength of arbitrary cross-section prismatic columns, which is especially useful for the preliminary design of longitudinal strength members. More recently, Professor Wierzbicki has joined with Professor Frank A. McClintock (Department of Mechanical Engineering at MIT) in a fundamental research project on the analysis and prediction of structural behavior involving both tearing and plastic failure. The concepts and methods they are developing can be applied to various kinds of high-impact loading, including crashes, explosions, and blasts.

FACULTY AND RESEARCH STAFF

Professor Arthur B. Baggeroer spent the spring term on a sabbatical leave at the Scripps Institution of Oceanography in San Diego, CA.

CAPT Randolph M. Brooks, USN, has been appointed to a three-year term as Professor of Naval Engineering. CAPT Brooks will become the Head of Course XIII-A, Naval Construction and Engineering, late this summer.

CDR Richard C. Celotto, USN, joined the faculty in the summer as Associate Professor of Naval Engineering and as Academic Officer of Course XIII-A, Naval Construction and Engineering. This is the first year of a three-year appointment.

Professor Chryssostomos Chryssostomidis spent the last three months of the year in Europe on a special assignment for the Office of Naval Research.

Professor Dyer was appointed the first Weber-Shaughness Professor in the Institute, effective December 1, 1989. Professor Dyer had earlier been widely recognized outside of MIT for his major contributions to science and engineering, for example, through his election to the National Academy of Engineering and several awards from government agencies and scholarly organizations. Now MIT has recognized not only his scholarly works but also his contributions to education and to collegial life at MIT.

Professor Leo Felsen was Visiting Professor in the Department for the academic year. He is a distinguished member of the faculty and former dean of engineering of the New York Polytechnic Institute. His activities at MIT included thesis supervision and collaboration in our program of research on structural acoustics.

Professor Ernst G. Frankel served briefly as Visiting Professor at the National University of Singapore and the Arab Maritime Transport Academy (Egypt). Professor Frankel is Senior Advisor on Ports to the Secretary General of the International Maritime Organization and a member of the Visiting Committee of the UN-sponsored World Maritime University in Malmo, Sweden.

Associate Professor Judith T. Kildow was appointed to the technical advisory committees of the Massachusetts Secretary of Environmental Affairs and the Massachusetts Bays Research Program.

Professor Emeritus Philip Mandel died December 18, 1989. He had been the Department's leader in the area of ship design for many years, having served on the faculty from 1957 until his retirement in 1980. He was the author of two texts, Ship Maneuvering and Control and Water, Air and Interface Vehicles.

Associate Professor Henry S. Marcus has been serving as chairman of a panel of the Marine Board of the National Academy of Sciences/National Research Council investigating tank-vessel design. The panel is working to identify vessel design alternatives, e.g., double bottoms and double hulls, and evaluate their economic, safety, and environmental benefits. Although such issues have been debated for many years, the need for definitive answers has become critical as a result of the EXXON VALDEZ grounding and the subsequent massive pollution of Alaskan waters. Professor Marcus's panel is charged with producing the needed recommendations.

Professor Koichi Masubuchi became the first Kawasaki Professor of Engineering at the beginning of the year. The chair was endowed by Kawasaki Heavy Industries, Japan. At the Second International Conference on Welding Research, held in Gatlinburg, TN, in May, 1989, Professor Masubuchi received an award "for outstanding contributions to the field of welding science and technology."

Professor Jerome H. Milgram was named the first William I. Koch Professor of Marine Technology. This chair was endowed by and named for Dr. William I. Koch, an alumnus of MIT's Course X. Professor Milgram has made fundamental contributions to a wide range of problem areas, including, for example, the containment of oil spilled on the water and the dynamics of large buoyant plumes (as produced by an oilwell blowout at sea). He is also widely known for his research and design relating to sailing yachts.

Professor J. Nicholas Newman was elected to the National Academy of Engineering last year, a fact that was omitted from the 1989 report of the Ocean Engineering Department to the President. He was also elected a foreign member of the Norwegian Academy of Science.

Professor T. Francis Ogilvie was the first recipient of the newly established William H. Webb Medal, awarded by the Society of Naval Architects and Marine Engineers for outstanding contributions to education in ocean engineering and naval architecture.

Assistant Professor Nicholas M. Patrikalakis was promoted to Associate Professor, effective the start of the new year. He has continued during the year as Doherty Professor of Ocean Utilization. Professor Patrikalakis has become widely known in just a few years for his leading-edge research on geometrical modeling (see description above under RESEARCH).

Associate Professor Henrik Schmidt was awarded permanent tenure, and he was appointed to a two-year term as Doherty Professor of Ocean Utilization. Professor Schmidt is known worldwide as a leader in the modeling of sound propagation in the ocean. He won this recognition largely through the development of a new methodology for predicting the acoustic behavior of a complex layered medium, an approach that he has implemented in a series of computer programs referred to generically as "SAFARI." Versions of SAFARI have been acquired by over 100 organizations in North America and Europe.

Professor Barrick F. Tibbitts, CAPT USN (Ret), has resigned from the faculty, to be effective at the end of the summer. For three years, he has been the senior US Navy officer on the Ocean Engineering faculty, serving as head of Course XIII-A, Naval Construction and Engineering.

Dr. George S. Triantafyllou, Principal Research Engineer, has resigned to take an appointment as Associate Professor of Mechanical Engineering in the Levich Institute of the City University of New York.

Associate Professor Michael S. Triantafyllou was promoted to Professor, effective at the start of the new academic year. He is universally recognized as an authority on the dynamics of complex cable structures, such as moored offshore platforms. In the last several years, he has applied his knowledge of such systems to the design and analysis of tethered unmanned underwater vehicles, and he has become an essential collaborator with the group at the Woods Hole Oceanographic Institution that developed the ARGO and JASON vehicles.

Professor J. Kim Vandiver stepped down as Director of the Experimental Study Group in the School of Science at the beginning of the year and then spent the fall term on a sabbatical leave at the Elf Aquitaine laboratory in Pau, France. Professor Vandiver has been named Chairman-Designate of the MIT faculty, with his appointment starting July 1, 1991. He previously served as Associate Chairman.

Associate Professor Dick K.-P. Yue had a sabbatical leave in the fall term, developing new research areas during an extended visit in San Diego, CA. He continued this activity in California during the spring term on an MIT off-campus research appointment.

ROBERT BRUCE WALLACE LECTURE AND PRIZE

Dr. Craig E. Dorman, Director of the Woods Hole Oceanographic Institution (WHOI), presented the annual Robert Bruce Wallace Lecture on October 25, 1989, on "The Challenge for Ocean Engineering." Dr. Dorman was Director for Anti-Submarine Warfare in the Navy's Space and Naval Warfare Systems Command until early in 1989, when he took the position as Director of WHOI.

Ms. Wendy Woods was the recipient of the 1989 Robert Bruce Wallace Academic Prize. She received her bachelor's degree in ocean engineering in 1989 and then started working for an SM in Course XIII-B, Ocean Systems Management. As an undergraduate at MIT, she completed two projects under the Undergraduate Research Opportunities Program (UROP), one on ocean acoustics (with Professor Dyer) and the other on the political feasibility of using a sludge-burning platform incinerator in Boston Harbor (with Professor Kildow). Outside of MIT, she is working on the development of a towed underwater oceanographic vehicle, which might possibly be used for the measurement of, say, biological oxygen demand in Boston Harbor and Massachusetts Bay.

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 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 John M. Hollerbach, 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 Knight has been developing a uniform, large scale, parallel symbolic supercomputer called *Transit* along with a massively parallel hybrid analog/digital machine for quickly solving coupled constraint problems. Professor William J. Dally is designing the J-Machine for efficient implementation of massively parallel message passing systems. Professor Gerald J. Sussman and Professor Harold Abelson lead a major new research program aimed, in part, at creating sophisticated problem-solving partners for scientists and engineers studying complex dynamic systems.

The Laboratory's 202 members include 22 faculty members, 15 academic staff, 36 research and support staff, and 129 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, Lockheed Missiles and Space Company, Martin Marietta, Mazda Motor Corporation, MCC Corporation, McDonnell Douglas Aerospace, NASA, NATO, NYNEX, Olivetti, Sandia National Laboratory, Sharp Corporation, Siemens, Sloan Foundation, and Sperry.

SPECIAL EVENTS AND BOOKS

During the past year, Professor Marvin Minsky won the coveted Japan Prize, Japan's highest scientific honor, for his work in Artificial Intelligence.

Also during the past year, highlights of the Laboratory's recent work were published in the two-volume collection *Artificial Intelligence at MIT: Expanding Frontiers*, edited by Professor Winston and Sarah A. Sheldahl, and published by the MIT Press.

Also published were *ONTIC: A Knowledge Representation System for Mathematics*, by Professor McAllester, *The Programmer's Apprentice*, by Drs. Rich and Waters, and *Shape from Shading*, edited by Professor Horn and Michael J. Brooks.

ROBOTICS

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 three fronts: organizing many behaviors into a coherent whole; developing perceptual systems that work in rapidly changing environments without a priori calibration; and producing extremely tiny robots.

During the past year, progress was made on a number of fronts. One wheeled robot learned distributed maps using an active, decentralized network. Another wheeled robot successfully navigated about its environment using real-time vision, and a self-calibrating physical model of the primate vestibular-ocular system was demonstrated. A six-legged robot learned to walk through the cooperation of independent behaviors controlling each leg. And the first piezo-electric micromotors built on silicon using photolithography were demonstrated.

Planning For Collision-Free, Compliant, and 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. During the past year, Handey has been extended in several ways. Handey can now 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 new algorithm for computing configuration-space obstacles.

Legged Locomotion

Professor Raibert and members of the Leg Laboratory have been studying legged locomotion in robots and

animals. In earlier years the group demonstrated dynamic machines that balanced as they ran. This work included one-, two-, and four-legged machines that ran in place, traveled at specified rates, maintained balance when disturbed, ran fast, and did simple gymnastic maneuvers. New algorithms were developed for studying passive dynamic running, and an internal combustion actuator was demonstrated. Galloping was achieved in laboratory experiments for a biped, and in computer simulations for a quadruped. Algorithms developed for robots are proving to be useful for controlling computer graphics animations of robots and animals.

Robot and Human Arms and Hands

Professor Hollerbach's research involves two major thrusts: the kinematics, dynamics, and control of human arms and robot manipulators; and the grasping, tactile sensing, and haptics of human hands and multi-fingered robot hands. With Professor Ian Hunter of McGill University, he has been measuring the joint mechanical properties of the unrestrained human arm during posture and movement, using a novel perturbation system involving air jets. He has developed a new technique for robot arm kinematic calibration, involving the use of closed-loop mobility rather than endpoint sensing. With Professor Jeffrey Lang of the Laboratory for Electromagnetic and Electronic Systems and Professor Hunter, he has been designing and testing new motors for a direct-drive arm. With Mr. Nat Durlach of the Research Laboratory of Electronics, he has been measuring the perceptual capabilities of the human hand.

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 reflexive grasping behaviors aimed at plan-free 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 is also being developed for the hand.

A new 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 of 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. 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 to unstructured grasping. A marine version of the arm has been developed in conjunction with Dr. Yoerger at the Woods Hole Oceanographic Institute and has been used successfully in several deep ocean explorations.

Advances have been made in understanding the dynamic characteristics of robot arms. This work has led to strategies for improving robot performance in several areas. Structural vibration of robots has traditionally resulted in unacceptable endpoint motions, particularly for light flexible arms. Within Professor Seering's

group, methods have been developed for moving flexible robots rapidly from point to point without exciting undesirable vibrations. During the past year, the ideas have been tested with good results on hardware and software simulations of NASA's Remote Manipulator System (also known as the Shuttle arm). An application involving disk-head motion is also under development.

Professor Seering's students also have been studying the problem of programming computers to perform automatic mechanical assembly. During the past year, work oriented at automatic force strategy learning has begun.

Motor Learning

Professor Atkeson and his group have been exploring paradigms for motor learning, improving performance 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, where a model of the controlled system is used as the learning operator to 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.

VISION

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 their 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. They are also beginning to study analog and hybrid VLSI implementations of the Vision Machine's main components. Current work focuses on recognition and on Machine Learning. In particular, they have begun to explore simple learning and estimation techniques for vision tasks. They have succeeded in synthesizing a color algorithm from examples and in developing a technique to perform unsupervised learning of other simple vision algorithms such as simple versions of the computation of texture and stereo. In particular, they have developed a new theory of networks for learning based on the recognition that learning input-output mappings from sets of examples, of the type that many neural networks have been tested on, can be regarded as synthesizing an approximation of a multi-dimensional function; that is, solving the problem of hypersurface reconstruction. Towards the goal of achieving much higher flexibility in the Vision Machine

they propose to explore (a) the synthesis of vision algorithms from a set of instances and (b) the refinement and tuning of preprogrammed algorithms, such as edge detection, texture discrimination, motion, color and calibration for stereo. Much of their effort will be focused on new schemes for visual recognition of 3-D objects, whose key component is the automatic learning of a large database of models. They aim to develop a prototype of a flexible vision system that can, in a limited way, learn from experience.

Stereo Vision

Professor Grimson and his students continue to work on the development of new stereo vision systems, and on their use in intelligent tasks. Recent highlights include a new stereo matching algorithm, the integration of stereo into a navigation system for a mobile robot, and work on object recognition from stereo data.

Recognition

Work on object recognition, directed by Professors Grimson and Lozano-Pérez, 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, and as part of a navigation system for autonomous vehicles. Recent efforts have focused on establishing formal results on the complexity of object recognition, on parallel algorithms for recognition, on the role of sensing strategies in recognition, and on methods for selecting salient data features on which to focus attention.

Other work, directed by Professor Ullman, is exploring the problem of three-dimensional object recognition. This research has been divided into two main topics. The first problem is that of image partitioning and selection. The goal of this processing stage being to select from the image a portion that is likely to contain an object of interest. The selection processes give 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.

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 scheme, initially implemented for flat machine parts, has recently been extended to handle complex three-dimensional objects with smooth surfaces. The second approach uses stored 2-D views of a hypothesized object to construct a new view in a manner dictated by the given view of an object to be recognized. The constructed view is then compared to the given view to verify the hypothesized object and its pose.

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.

Motion Vision, Low-Level Integration, and Photogrammetry

Professor Horn and his students continue to 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.

In the area of Photogrammetry, Professor Horn has developed a new iterative algorithm for relative orientation, a central problem in calibrating cameras both in binocular stereo and long-range motion vision. The new least squares method, using unit quaternions to represent rotations, does not require a starting guess, finds all solutions, and is very efficient.

Finally, a chip have 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 one to reduce certain area based computations to contour computations; the other result uses the equivalence of two different uses of a 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 hundreds of millions of arithmetic operations 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.

NATURAL LANGUAGE

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 implemented that allows one to investigate different constraint-ordering possibilities so as to optimize language processing. This is the first complete parsing implementation of the current linguistic theory that has been developed at MIT by Chomsky, Hale, Higgenbotham, and others. The system also includes a learning component to automatically "compile" its constraints into those required for optimally parsing a given sentence. His group also improved on a universal representation for word meaning that considerably advances existing language translation systems, successfully applying this method to problematic translation examples in Spanish and German. Professor Berwick's group has also developed a highly efficient natural language parser that can analyze large amounts of text. For example, the entire 1988 *Wall Street Journal* in just several hours. This parser is being used to automatically learn about new words just as people do. Finally, a new collaborative effort into the design of modular language processors was continued jointly with the Cognitive Science Center. This has included the analysis of a million-word English language database and the design of tools for "smart" dictionary analysis for several very different languages.

LEARNING AND COMMONSENSE REASONING

Professor Winston's theory of reasoning by analogy consists of an English understanding module, developed and implemented by Mr. Boris Katz, an analogizing module that reaches conclusions about a given situation by using a remembered precedent, and a rule builder that constructs if/then rules. During the past year, the system was extended through a mechanism that enabled the system to learn from its own mistakes.

The English understanding module, START, developed by Mr. Boris Katz, analyzes English text and automatically transforms it into an appropriate representation for either analogical reasoning or direct interrogation by human users. In August, 1989, during the Voyager Neptune encounter, the START system was used by many journalists at the Jet Propulsion Laboratory to answer questions about the encounter, the Voyager spacecraft, and the Solar system.

Also during the past year, Dr. Rick Lathrop brought established learning heuristics together with the power of parallel processing to produce a learning system aimed at improving protein-recognition patterns. In sev-

eral experiments, involving hundreds of examples, Dr. Lathrop's system was able to discover new, improved patterns starting from seed patterns supplied by human biologists.

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.

Recent work has been characterized by the completion of 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 has also progressed on two new systems. One has been designed to aid in 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 was designed to explore the fundamental problem of model selection: how does an engineer decide which model (that is, which approximation) to use when solving a problem.

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 communicating accurate manufacturing cost information to a product engineer at the detailed design stage of product development. Another project develops a human-computer interface for geometric modeling in product design. This interface is a kind of intelligent modeling clay in which an engineer's hand actions are interpreted as operations on a graphical description of a part. Professor Ulrich also has been working on the problem of synthesizing an engineering structure in response to a specification of its connections to other parts of a product. The work is currently focused on sheet metal parts such as brackets in a photocopier. Finally, Professor Ulrich uses the 16,000 processor Connection Machine to develop novel schemes for simulating the mechanical behavior of materials.

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 major demonstration of their approach to computer-aided software engineering in the area of requirements acquisition and analysis, called the Requirements Apprentice. They are also working on automated reverse engineering (reconstructing the design of a program from just the source code), automated program optimization (using a library of reusable software abstractions), and intelligent assistance for software design.

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 aimed at developing new computer representations and reasoning mechanisms that will enable intelligent systems to autonomously design, monitor, and understand complicated physical systems through appropriate mixtures of numerical and symbolic computing. Members of the group have shown how to use symbolic algebra to compile high-level descriptions, such as circuit diagrams, directly into numerical modeling and simulation programs whose elements can be automatically generated from a library of mix-and-match numerical subroutines expressed at appropriate levels of abstraction. Work by Abelson (the Bifurcation Interpreter) and Yip (KAM) has demonstrated how to encode knowledge of modern dynamical systems theory into intelligent programs that automatically control and monitor numerical experiments and interpret the results in qualitative terms. Other programs developed by the group have been used to help discover new results in theoretical hydrodynamics. The group is also developing a *Super-computer Toolkit* that supports the routine, or even automatic, synthesis of high-performance but low-cost special-purpose computers.

HARDWARE AND SOFTWARE ARCHITECTURES

Message-Passing Semantics

The Message-Passing Semantics group, under the guidance of Professor Hewitt, has been developing the foundations for ultraconcurrent systems that perform robustly in changing environments. An ultraconcurrent system is one that performs its computations with as much concurrency as possible compatible with the laws of physics. 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 theoretical, architectural, and linguistic aspects of organizational systems composed of humans and telecomputer systems.

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 working on the design of the J-Machine, a fine-grain concurrent computer that offers performance of 10^3 times a conventional mainframe and tests a number of new concepts in interconnection networks, addressing mechanisms, processor architecture, computer arithmetic, and concurrent software systems. A routing chip and an arithmetic chip designed to test portions of the J-machine design have been successfully demonstrated in the laboratory. During the past year, the group has constructed instruction-level, register-transfer level, and gate-level simulations in collaboration with Intel corporation. An operating system and compilers for the Concurrent Smalltalk and Concurrent Aggregates programming languages have been written for the machine. Application studies are currently underway.

BASIC THEORY

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 “crashless” performance.

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.

PATRICK H. WINSTON

DIRECTOR

Biotechnology Process Engineering Center

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. This Center was approved in 1987 for an additional five years of support beginning February, 1988 through January, 1993. As an interdepartmental Center, the BPEC reports to the Dean of Engineering, Professor Gerald L. Wilson. The Director of the Center is Daniel I.C. Wang, Professor of Chemical Engineering. Three Associate Directors assist in the overall operations of the Center. These include 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.

In 1989, a total of twelve faculty members participated in the Center's activities. Within MIT, two departments from the School of Engineering have faculty participants and these are the Department of Chemical Engineering and the Department of Electrical Engineering and Computer Science. From the School of Science at MIT, faculty participants are from the Biology Department and the Whitehead Institute. This Center also has two outside universities which participate in the overall activities. These are from the Department of Chemistry at Harvard University and the Department of Chemical Engineering and Biochemical Engineering at Rutgers University.

A summary of the personnel associated with this Center during 1989-1990 is tabulated below.

• MIT Undergraduates (UROP)	- 132 (10 Departments)
• Non-MIT Undergraduates (REU)	- 36 (16 Universities)
• Graduate Students	- 53 (4 Departments)
• Technical Assistants	- 7
• Post-Doctoral Associates	- 24
• Visiting Scientists & Engineers	- 9
• Visiting Faculty	- 7
• Other Administrative Personnel	- 9

TOTAL 258

The major financial support is provided by the National Science Foundation. Additional support for educational activities for the MIT students is provided by the National Institutes of Health (NIGMS). Twenty-four companies provided additional financial support in the forms of industrial contracts and equipment donations. Lastly, eighty companies provided unrestricted funds to the Center and its faculty in 1989-1990.

EDUCATIONAL ACTIVITIES

The Center's faculty members continue to teach an interdisciplinary undergraduate course, 7.52J/10.56J, Biotechnology of Mammalian Cells. The funds to the faculty and ching assistants for implementing this course were provided by the Center. The Undergraduate Research Opportunities Program (UROP) continues to be an active program within the Center. In 1989-1990, a total of one hundred-thirty-two MIT undergraduates

from ten departments participated in the Center's research. An undergraduate outreach program funded separately by the National Science Foundation under the Research Experience for Undergraduates (REU) supported 32 non-MIT students in 1989-1990. These non-MIT REUs were from sixteen different universities and colleges throughout the United States. We continued our seminar program entitled, "UROP and REU Seminar" where the undergraduates present on a weekly basis their research experiences to the Center's personnel.

At the graduate level, efforts were continued to bringing interdisciplinary concepts into the course teachings. A new outreach program was initiated in 1989 with the additional financial support from NSF and unrestricted funds from the Center. This Program was to provide opportunities for faculty and students from underrepresented minority colleges and universities to perform research at our Center. During the summer of 1990, Professor Dorethea Foushea from the Department of Biology at the North Carolina Agricultural and Technical State University was a visiting professor in the Center. In addition, three other minority students also participated in this new outreach program.

At the graduate level, the Biotechnology Process Engineering Center helped to launch the Interdepartmental Biotechnology Training Program. This new effort involved 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. Through NIH (NIGMS), a training grant to support fourteen pre-doctoral candidates for the first year and up to twenty-one trainee fellowships for the third through the fifth year has been secured. New cross-disciplinary courses will be developed for this new program.

Industrial educational activities were achieved through the Special Summer Course Program at MIT. In 1989, four special summer courses under the auspices of the BPEC were presented. The four summer courses were, "Fermentation Technology", "Biotechnology: Principles and Processes", "Downstream Processing", and "Modeling, Simulation and Optimization of Chemical Processes". During 1989, a four-day course on "Downstream Processing" taught by 5 BPEC faculty members was presented at Merck, Sharp and Dohme's West Point facility with over one-hundred people attending.

CURRENT RESEARCH

The vision and goal of this ERC are to develop advance 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.

Three research thrust areas are being pursued in this Center. The first area is focused on the "Genetics, Molecular Biology and Biochemical Principles in Protein Production". The overall goals are to find generic means for the genetic construction and identification of animal cells to increase recombinant protein expression and secretion leading to increased levels of recombinant proteins in eukaryotic cells. A novel gene amplification strategy has been developed to increase gene copy number using an SV40 vector in combination with temperature sensitive mutants. This finding provides a new method for both rapid selection and high level expression of recombinant proteins. Two important goals are to better understand post-translational protein modification and protein secretion. Achievement of this goal is important to the

development of advanced manufacturing processes. A bottleneck in the transport of recombinant proteins in the endoplasmic reticulum proteins has been found; by unraveling this rate controlling step, we should increase the rate of protein secretion. A cross-disciplinary effort to enhance protein secretion through both molecular biology and engineering concepts has been initiated. Protein secretion is affected by control of ion channels. Bioreactor operating strategies are used to separate growth and protein secretion and aid protein purification. Lastly, a system's approach has been taken to identify bottlenecks such as end-product inhibition and devise strategies to increase product formation rate.

The second thrust area is focused on the "Engineering Principles in Protein Production". Following identification or construction of a cell line that efficiently combines the protein expression, processing and secretion, our next target is to provide an optimal environment for growth and production. Growth and product synthesis depend on many environmental factors, physical and chemical, which must be not only adequately identified and understood, but also quantitatively described for optimal bioreactor operation. Cell culturing procedures are extremely sensitive so that good cell/protein manufacturing processes need to be closely monitored and controlled. Furthermore, much of the required knowledge may be qualitative or may reside dormant with the expertise of the practitioners; this necessitates the use of methodologies from the field of expert systems to achieve the best cell/bioreactor combination. These problems define our goals in "Engineering Principles in Protein Production", as well as our strategy in meeting these goals. Our overall objective is two-fold: first to elucidate the engineering principles through complete kinetic description of environmental effects and systems integration for the selection, design, and operation of optimal bioreactor systems for protein production. Second, to develop, test, and demonstrate with a variety of standard and new (recombinant and other) cell lines, conventional and novel bioreactor configurations for their feasibility and operational improvements. The specific research focus in this area includes both anchorage-dependent and anchorage-independent cells. Basic knowledge in fluid mechanics in bioreactors are sought. Increased rates of operation are sought by increasing cell density by cell flocculation, novel entrapment matrices (ceramic monoliths and glass fibers) and environmental and genetic means to control and reduce end-product inhibition. Lastly, a systems' engineering approach includes the use of expert systems and intelligent sensors for monitor and control.

The third thrust area is focused on "Downstream Processing in Biotechnology", which is a major barrier in manufacturing of therapeutic proteins. Our efforts in downstream processing focus on improving current technology and developing new principles. To improve current technologies, we focus on problems with membrane processing. This includes electrical control of membrane permeability, rotary devices to induce secondary flow to minimize fouling, and development of continuous affinity recycle extraction (CARE). The focus on chromatography processes recognizes the importance of immunoabsorption and addresses the barriers of operation and scaling this technique. We are developing new recovery technologies which include biphasic aqueous extraction and micelles for selective extraction of proteins. A major barrier in the recovery complex proteins is associated with efficient refolding of proteins during processing. We seek solutions to this problem through the use of reversed micelles as a medium for refolding, and new concepts of antibody-assisted refolding to catalytically enhance the rate and to stabilize properly folded molecules. Considerable attention is given to experimental verification of models for simulation and design. These models are important for development of computer-aided design tools using both ASPEN PLUS for process simulation and expert systems for designing advanced recovery strategies.

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 is a total of sixty-one companies in this Program, representing the entire spectrum of the biotechnology industrial sectors. During 1989-1990, a total of twenty-nine collaborative industrial projects were in place with an additional eleven industrially sponsored research projects. Lastly, during 1989-1990, there were twelve industrial scientists and engineers in residence at this Center.

To affect the timely and efficient transfer of technology, two separate offices have been established. The Technical Coordination Office handles the visits from companies, annual symposia and the special workshops. The Technology Transfer Office has established a data-base on all of the research projects within the Center and provides this information to the Industrial Consortium members. The activities of the Technology Transfer Office of the Center are also closely coordinated with MIT Technology Licensing Office.

Special efforts are also made by this Center to disseminate information from its research programs. Four special workshops were held for the Industrial Consortium members. The workshop on "Animal Cells Science and Technology" with a total of twenty-eight attendees representing twenty companies. The second workshop entitled, "Downstream Processing" with a total of Forty-three attendees representing twenty-nine companies. The third workshop entitled, "Process Control and Scale-Up" with a total of thirty-seven attendees and representing twenty-one companies. The fourth workshop entitled, "Advances in Membrane Technology for Bioprocesses" with a total of sixty attendees and representing thirty-eight companies.

Below is a summary on some of the other achievements from the BPEC during 1988-1989:

- Publications - 175
- Presentations at Conferences and Symposia - 98
- Industrial Seminars - 32
- University Seminars - 61
- Theses - 8
- Company Visitors to BPEC - 100

NEW APPOINTMENTS AND NEW INITIATIVES

There has been no new faculty appointments to the Center during the past year. However, through the new Underrepresented Minority Initiative, Professor Dorethea Foushee from the Biology Department, North Carolina Agricultural and State Technical University was appointed as a visiting professor in the Center. The Center plans to continue and to increase participation and collaborations with other minority colleges and universities. Discussions are in progress to establish a collaborative effort with the Chemical Engineering Department, Howard University and this Center.

To provide a global biotechnology relationship with the international section, the Center was instrumental with the support of NSF to have hosted a workshop with the Federal Republic of Germany. This exchange program will be continued in the future years.

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 learners 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 1989-90 academic year, 90 professionals participated in the Advanced Study Program, 32 from the United States and 58 from 22 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 Modern Computer Methods and American Language and Culture.

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 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.

Video based educational programs include professionally-produced studio and classroom courses focusing on recent developments in MIT research. 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.

All 1989-90 productions were produced in the CAES professional-quality television studio housed in Building 9. Designed to meet the diverse needs of the Institute, the television studio complex has increased Center productivity, enhanced video production, and facilitated the application of new video technologies. Recent releases include: Television Systems Design: from NTSC to HDTV by Professor William Schreiber, Analysis of Welded Structures by Professor Koichi Masubuchi, and Machinery Noise and Diagnostics by Professor Richard Lyon. Courses in progress 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 and Quality Function Deployment by Professor Don Clausing, 2-D Signal and Image Processing by Professor Jae Lim, and Corporate Entrepreneurship by Professor Edward Roberts. CAES video programs continue to be produced primarily by Center staff using Center-owned equipment.

In order to enhance the Institute's well established role in Continuing Education, CAES is pursuing new initiatives in educational programming to strengthen MIT's coupling to Industry, both local and out-of-state. These initiatives include offering non-credit Saturday Programs on Campus or "A Day with an MIT Professor." These short programs are tutorial in nature and emphasize fundamentals. Participants spend a day with a faculty member and come away with the feeling that an opportunity to examine a topic in depth has been explored through direct interaction.

This concept was tested on two Saturdays in the spring and attracted more than 160 participants from the greater Boston area, as well as from out-of-state. The programs presented were: Technology Transfer and Reward Systems for Professionals by Professor Allen; Advances in Multivariable Control System Design by Professor Athans; Nonlinear Finite Element Analysis of Solids and Structures and Nonlinear Finite Element Analysis of Fluids and Fluid-Structure Interactions by Professor Bathe; Mobile Robots by Professor Brooks; Concurrent Engineering by Professor Clausing; Lasers--Who Needs Them and Optical and Fiberoptical Sensors by Professor Ezekiel; Project Management by Professor Frankel; Smart Engines by Professors Greitzer and Epstein; Enzyme Technology by Professor Klibanov; Corrosion Resistance of Advanced Engineering Materials by Professor Latanision; Polymers and Polymer-Based Composites by Professor McGarry; Cryptographic Security by Professor Micali; Heat Transfer in Design and Processing by Professor Mikic; Knowledge-Based Expert Systems for Engineering by Professor Sriram; The Dynamics of Innovation in Industry by Professor Utterback; Optical Information Processing by Professor Warde; and 3D-Computer Graphics by Professor Zeltzer.

In addition, the Center, in partnership with Telecommunications Services, has installed a satellite downlink to receive a variety of educational programs which are being made available to the MIT community via the campus television network. We will also uplink selected timely management and engineering subjects. MIT broadcasts will be organized around single themes focusing on practical applications and useful information taught by one speaker and conducted over several hours in a single day. We will transmit simultaneously on KU-band and C-band to businesses and government agencies. Two satellite broadcasts are now scheduled for the Fall of 1990: Laser Fundamentals and Applications for Managers and Engineers, and Taguchi Quality Engineering System for Robust Design.

The summer of 1990 will be the fourth year of 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 250 faculty will be attending such programs this summer. 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). In the summer of 1990 five out of the nineteen courses will be offered at MIT.

MIT's Video Production Services, serving the Institute for over ten years, has been integrated into the Center and will continue 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 CAES facilities. Services include, among others, a full-production television studio, a television classroom, videotaping on location, on 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 five 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.

EDUCATION

New initiatives in policy education have included the addition of an option for concentration in social science in the Technology and Policy Program (TPP), the expansion of the leadership component of the TPP core curriculum, and the development of an integrated program of summer courses on technology-intensive policy issues. These new developments represent the Center's efforts to adapt policy education to the changing needs for both continuing education for mid-career policy professionals and also for graduate training in the field.

TPP is a graduate program preparing students for leadership in technology-intensive policy areas. About 60 students are enrolled. Graduates enter government, the private sector, and teaching at the university level. Students are admitted through academic departments at MIT and have traditionally come from fields of engineering and science. This year, TPP added a second track for students wishing to emphasize political, economic, and organizational aspects of technology and policy. The new curriculum is fully integrated with the original program, and all students share the core Proseminars and requirements for basic subjects in technology and policy. The first students were admitted this year to the new concentration in the program through the Department of Political Science. Also as of 1989-1990, students may receive course credit for off-campus TPP activities through TPP 101, the group leadership seminar. An Outward Bound type activity held on Thompson's Island in Boston harbor is now a regular feature of the seminar.

During this year, CTPID-affiliated faculty organized their summer courses into a coordinated program to be offered for the first time in 1990. The courses in the program will be linked by the common usage of policy modules developed specifically for the program by the course leaders. The modules will derive from common areas of interest in technology-intensive policy such as the identification of interests; political and legal systems impinging on technological options; the modes of action and influence different actors might muster; and the perspectives from which problems might be identified. The plan is to create a new "infrastructure" for course offerings in technology and policy, some of which have been given independently before, and some of which are being offered for the first time.

The Chemicals in the Environment course sequence, developed by the Hazardous Substances Management Program (HSMP), now in its third year, has continued to attract ever larger enrollments drawn from several departments and schools at MIT and other Boston area universities. The four courses, which may be taken separately or sequentially, give graduate and undergraduate students a core of integrated subjects enabling them to be effective in the area of hazardous substance management. The courses have been structured to

provide a systematic and interdisciplinary look at the critical issues of chemicals introduced into the environment.

RESEARCH

Center research programs have gained the support of industry, government, labor, and public interest groups in the study of a wide-ranging group of issues. Center research is growing in several program areas:

Industry Studies

Industry studies are developing the data bases and theoretical approaches for decision making in technology-intensive industries. Research at the Center has been directed particularly at industrial systems involving international dimensions, in terms of communications, materials, and markets.

*The International Motor Vehicle Program (IMVP) has emphasized investigations of the world-wide components industry, the challenges facing "new entrant" countries and companies, and the technology and policy implications of "smart vehicles/smart highways" in the US and Europe. Building on IMVP research in the latter area, Professor Daniel Roos is heading a study of advanced vehicle and highway technologies for the Transportation Research Board of the National Research Council. During 1989-90, IMVP leaders have coauthored a volume consolidating the most important findings of the Program's four-year study of "best practice" in the industry. It will be published in summer 1990. Translations into several languages are being prepared simultaneously. The book will be presented at a major meeting in Japan in September 1990.

*A group of CTPID-affiliated faculty members under the direction of Professor Joel Clark (Department of Material Sciences and Engineering) is assisting the government of Portugal to determine what type of technological infrastructure would best enable the nation to compete in Europe and world wide. The faculty involved, in coordination with Portuguese researchers, are studying options for the development of a materials-based industry, for example, the possibilities for investment casting.

*International competition in high technology, particularly computers and semiconductors, has been a focus of CTPID interest since its inception. Research at the Center will be presented to the public in a forthcoming book authored by Dr. Charles Ferguson (CTPID), who will share his views on the future of US competitiveness in high technology in the lead story in the *Harvard Business Review* for July/August 1990.

Environment

At CTPID, studies of the "environment" include investigations not only of human impact on natural processes, but also the social, cultural, and political environments which shape these interactions.

*Research at the Hazardous Substances Management Program (HSMP) now includes investigations of the incineration of hazardous waste; siting policy for disposal facilities; computer-supported negotiation; corporate environmental management policy; health effects of incineration; and groundwater contamination. The Program is directed by a group of MIT faculty including Professors David H. Marks (Department of Civil Engineering); Daniel Roos (CTPID); Adel Sarofim (Department of Chemical Engineering) Lawrence E. Susskind (Department of Urban Studies and Planning); William Thilly (Center for Environmental Health Sciences); and Dr. John E. Ehrenfeld, Coordinator of the Program. An important HSMP initiative this year has been the investigation of corporate environmental management policy and practice. The MIT Working Group on Business and the Environment has brought together corporate and environmental leaders, senior government officials, MIT and other faculty, and graduate students in a monthly seminar to discuss how businesses have organized internally to manage environmental affairs and the implications for corporate strategy. In June 1990, HSMP convened a major conference of leaders from government, private, and public interest groups to discuss issues surrounding the training of incinerator operators and related issues of monitoring, building public trust, and ensuring regulatory compliance.

*The quarterly journal *Environmental Impact Assessment Review* published two special issues in 1989-1990. The first, developed in coordination with the HSMP, explored the issues involved in siting incinerators for municipal solid waste. The second focused on the multifaceted international issue of the social impacts of development, and emphasized the need to link theory and practice. The *Review* is directed by Professor Susskind, Senior Editor, and Teresa Hill, Editor.

*A research team led by Professor Nicholas A. Ashford (School of Engineering) is concerned with legal and regulatory approaches to the control of toxic substances and the impact of law and regulation on the innovation process. This year, the group has investigated the monitoring of people whose communities have

been exposed to toxic substances and incurred associated risks to health. Another project is designed to identify long-term strategies for encouraging technological change to prevent chemical accidents and spills. In the area of risk assessment and management, Center-based research has advanced the development of techniques for quantitative risk assessment for chemicals. Professor Ashford's work on chemical sensitivity, performed for the State of New Jersey and published this year, was awarded the Macedo Award established by the Pan American Health Organization for the promotion of awareness of environmental health issues. This spring, he was appointed to a three-year term as chairman of the Committee on Technology Innovation and Economics, part of the National Advisory Council for Environmental Technology Transfer.

Communications

Communications is an technology-intensive policy area in which private and public interests are closely linked. The Center is supporting a range of new initiatives investigating technical and policy options for advanced communication systems.

*The Center's Research Program in Communications Policy (RPCP) is developing a Broadband Technology and Policy Project to facilitate research on technology policy-making processes and alternatives. Recently, members of the MIT program initiated a cross-industry Committee on Open High Resolution Systems (COHRS) to facilitate standard-setting in the US. The decisions of this group will be critical to the development of international communications, with implications for industry, research, and public policy. One of the Center's four visiting scholars this year, Dr. Jacob Baal-Schem of Tel-Aviv University, has been working with the communications group on the implications of integrating a multiplicity of electronic systems into homes.

*Interaction between public and private interests and Institute scholars is a cornerstone of CTPID communications research. The Center sponsors the Communications Forum, a seminar series supported by communications-oriented firms and government agencies affiliated with the Industrial Liaison Program (ILP). ILP also recently sponsored a symposium on "Telecommunications Technology and Policy for the 21st Century" for which Center Director Daniel Roos served as co-chair. The objective of the meeting was to discuss the technical requirements and policy implications of the burgeoning global communications industry. Looking beyond the strictly technological issues involved, the symposium organizers invited members of the business, planning, and policy communities to share perspectives with MIT researchers working at the cutting edge of developments in computer science.

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, and Sloan School of Management.

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, 126 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 grew by over 50 percent from 1988/89 to a level in excess of \$3 million.

In this report, we highlight several programs involving faculty and staff from around the Institute.

University Transportation Centers Program

The Region One University Transportation Center (UTC) was established at MIT on September 30, 1988. It is one of ten such Centers selected by the US Department of Transportation through national competition.

The Region One UTC is led by MIT, and it includes a consortium of private and public academic institutions in the six-state New England region. The consortium includes the John F. Kennedy School of Government at Harvard University and the Universities of Connecticut (at Storrs), Maine (at Orono), Massachusetts (at Amherst), New Hampshire (at Durham), Rhode Island (at Kingston) and Vermont (at Burlington). Also included in the consortium is active participation by North Carolina A&T University, located in Greensboro, North Carolina. NCA&T is a historically black college having a long-term relationship with the University of Massachusetts. Their participation is helping us to provide a positive outreach program to minority faculty and undergraduate and graduate students. Thomas Humphrey, Principle Research Associate at MIT, serves as the Region One UTC Director.

The objectives of the Region One UTC focus on establishing a collaborative program with private and public universities to undertake both basic and applied research designed to:

- Integrate technology and advanced methodology into the design and operation of transportation systems;
- Incorporate leading edge technological and management innovations for industry use;
- Provide enhanced opportunities for interaction between universities and the public and private sectors; and
- Attract more individuals to transportation research and education programs.

The twelve projects selected by the Region One UTC for the first year were completed by December 31, 1989, and the second year is now well underway. The first year's program provided the resources needed to establish a comprehensive regional program of research and education. Foremost among the first year's accomplishments was the development of a close-working relationship among the consortium universities and the industry through such activities as regular faculty seminars at Harvard on transportation and land use development; a workshop on bridge design and maintenance at MIT; and seminars at MIT on Region One activities. In addition to these activities, funding from the program has helped support 22 graduate students and five undergraduates, as well as the completion of a number of master's theses and PhD dissertations.

In the second year of the program, the Region One UTC research themes focus on New England's highest-priority transportation issues. The three themes for the second year are: (1) strategies to reduce congestion; (2) innovative ways to improve and extend the life of transportation infrastructure facilities; and (3) technological innovation to address surface transportation issues, especially intelligent vehicle highway systems (IVHS see later section).

Nine research projects are currently underway, and they include highway, transit, and multimodal activities. In addition, the Center has provided seed funding for four projects that offer the opportunity of developing new and innovative ideas that have the potential for establishing new research directions. The second year program is also providing research assistantships for over 20 graduate students and support for a number of undergraduates.

The Region One UTC submitted its plan for the third year to US DOT on May 31, 1990. The Region One Center has selected a third-year theme of **transportation management, policy, and operations**. The program evolved into this theme because the consortium universities have established and recognized strengths in those areas, and because of the urgent need to manage and operate the region's existing facilities and services more effectively.

The third year program has an increased emphasis on education. The objective is to make across-the-board advances in attracting and educating the next generation of transportation professionals by expanding upon the many excellent transportation programs that have been in existence among the consortium universities for decades. The third year education component is composed of graduate degree-granting programs, undergraduate initiatives, senior executive education, and short courses for mid-career transit managers. The program will enroll a number of new graduate students at MIT and at other consortium universities with UTC fellowship support, provide new opportunities for undergraduates and senior executives, and train mid-level transit managers throughout New England.

The Research Component will focus on (1) multimodal strategies to alleviate urban and suburban congestion; (2) technological innovations in surface transportation; (3) public policy formulation and implementation; (4) transportation systems operations and management; and (5) managing transportation infrastructure.

These foci are a natural result of the balanced multimodal transportation research program that has evolved in the first two years of the program. At this point, the Region One UTC has evolved into a coordinated set of activities that gives appropriately balanced emphasis to the region's transit and highway needs. The participants are particularly pleased with the ability of the consortium universities to work together to build upon existing activities, and to begin new initiatives for educating transportation leaders for the future.

Among the MIT faculty who have participated in the Region One UTC program are: Professors Moshe Ben-Akiva, Richard de Neufville, Joseph Ferreira, Jr., Ralph Gakenheimer, Haris Koutsopoulos, Richard Larson, Victor Li, Thomas Magnanti, Shyam Sunder, Joseph Sussman, Nigel Wilson; Dr. Kenneth Maser; and Mr. Humphrey.

Intelligent Vehicle Highway Systems

The development of intelligent vehicle highway systems (IVHS) in the United States is clearly an important new frontier for the transportation sector. The Center, together with the Center for Technology, Policy, and Industrial Development, is pursuing this research initiative. As we strive to reduce congestion and improve safety, the use of advanced technology in computers and communication can greatly improve highway transportation. At MIT, a number of projects are currently underway to investigate various aspects of the subject, ranging from overviews of system-wide concerns to tightly-focused studies of specific technologies. Some of the projects have just begun, some are recently completed, but all represent a growing commitment among our faculty.

The Benefits of IVHS. *Joseph Sussman, Director, Center for Transportation Studies.* A working group to develop initial estimates of benefits that might accrue from IVHS technology, and to create a framework for analyzing those benefits.

Assessing the Technologies. *Daniel Roos, Japan Steel Industry Professor of Engineering, Director, Center for Technology, Policy and Industrial Development.* A committee to evaluate IVHS technologies and to make recommendations to the Transportation Research Board as to what should be done in the United States.

International IVHS Activities. *Hans Klein, Center for Technology, Policy, and Industrial Development and Department of Political Science.* An investigation of IVHS research and development in Western Europe and Japan, and the relation of these to the US program.

Northeastern States Demonstration. *Thomas Humphrey, Principal Research Associate and Lecturer in Civil Engineering.* An initiative to develop a demonstration project of advanced transportation science and technology in the Northeast.

Boston Region Demonstration. *Thomas Humphrey, Principal Research Associate and Lecturer in Civil Engineering.* A project seeking ways to maximize the benefits of new IVHS technologies being installed around Boston by providing linkages between them.

Analysis of Traffic Congestion and Driver Information Systems. *Moshe Ben-Akiva, Professor of Civil Engineering.* Projects to explore the effects of driver information systems on overall traffic congestion levels.

Designing In-Vehicle Navigation and Route Guidance Systems. *Haris Koutsopoulos, Assistant Professor of Civil Engineering.* An exploration of specific design aspects of route guidance systems, under real time operations, that directly affect not only the amount of data needed, but also the performance of the systems.

Impact of New Technology on Safety and Human Factors. *Thomas Sheridan, Professor of Engineering and Applied Psychology, Department of Mechanical Engineering.* A project to examine driver mental workload and performance decrement as a function of sensing and display-control technology.

The Backseat Driver: An Experiment in Driver Information. *Christopher Schmandt, Principal Research Scientist, and James Davis, Research Associate, The MIT Media Laboratory.* A project exploring the use of synthetic speech for real time direction-giving.

Geographic Information Systems for Driver Information. *Richard de Neufville, Professor of Civil Engineering and Chairman of MIT's Technology and Policy Program.* A project to demonstrate the practical implications of digitized street-level "maps" of the United States for transportation purposes, using case studies of applications such as police car dispatching and the use of on-board computers by courier services.

Geographic Information Systems for Transit Agencies. *Joseph Ferreira, Associate Professor of Urban Studies and Operations Research; Director, Computer Resource Laboratory, School of Architecture and Planning.* Research to identify, compare and demonstrate alternative strategies for integrating geographic information system technologies into transportation management and operations, focusing particularly on transit-related applications.

Smart Traffic Signals. *Richard Larson, Professor of Electrical Engineering.* A project to develop computer models for evaluating the performance levels of traffic control systems now in use, and to apply these models to traffic control systems of the future.

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 50 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.

This year, for the first time, we had available to us University Transportation Centers fellowships for students entering in September 1990. These are funded through the US Department of Transportation, University Transportation Centers Program, described more fully earlier in this report. Those fellowships are intended to attract high quality students to study in the transportation area. Four fellowships were awarded to incoming MST students.

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.

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 1989/90, the doctoral award was split between Patrick Little and C. S. Venkatakrisnan. For 1990/91, we again split the award between Isam Kaysi and Garrett van Ryzin. In addition, for 1989/90, we awarded partial fellowships to two particularly able MST students, Thomas Grayson and Allen Downey. For 1990/91, the MST fellowship was awarded to Lucy Jen.

Further, we continued to provide partial support for needy graduate students in transportation.

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. The 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, Maersk Lines, Inc., Nabisco Brands, 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.

A good example of this interaction is the ongoing research relationship between CTS and one of our affiliates, the Burlington Northern Railroad. Currently, a number of important research efforts are sponsored by Burlington Northern at CTS, including work in track maintenance (Carl Martland), empty car distribution (Professor Yossi Sheffi), and information systems (Dr. Amar Gupta).

In keeping with the goals of the Affiliates Program, each year an affiliate firm hosts a day-long meeting for the others on a subject of mutual concern. This past December, approximately 40 senior executives of shipper and carrier organizations met aboard the Queen Mary in Long Beach, California, to focus on "Meeting the Challenge: Integrating International and Domestic Distribution Operations." The meeting was jointly hosted by American President Companies and the Southern Pacific. The international dimension is of increasing importance in transportation logistics, and the various talks and shipper/carrier panels found a receptive audience. Professor Donald Lessard of the Sloan School of Management and Professor Henry Marcus of the Department of Ocean Engineering as well as Professor Sussman, the Director of the Center gave talks to the group. In addition, the group toured APL's C-10 Ultra Panamax Containership, and Southern Pacific's Intermodal Container Transfer Facility.

Next year's meeting will be hosted by Federal Express at their Memphis Hub.

Summer Executive Program

Last summer, the Executive Program in Transportation offered a new course on **Strategic Management**. The two-day course treated the design and implementation of business strategies in markets where firms are highly interdependent with their customers. Its focus was on transportation and distribution where carriers and shippers now work very closely together under long-term partnership contracts. Among the topics covered are the growing economic trend toward business partnerships, the elements of successful partnerships (including the technological requirements), the projected effect of government regulation on partnerships, and the implications of partnerships for labor/management strategies. The subject was jointly chaired by Professor John Henderson of the Sloan School of Management and Gerard McCullough of CTS.

This summer, we will again 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.

Technical Seminars

The Industry Affiliates Program sponsors technical seminars for member firms. This year, two seminars were offered.

In November 1989, a seminar on "Electronic Integration: Managing Strategic Partnerships Using Information Technology" was offered by Professor Henderson and Professor N. Venkatraman. Strategic partnerships are increasingly becoming a critical management issue in the transportation sector. This seminar explored the emerging issue of electronic integration between suppliers and buyers, and the changing role of transportation companies.

In April 1990, a seminar was held on "Advances in Network Analysis and Operations Research in Transportation and Logistics." Chaired by Professor James Orlin of the Sloan School of Management, this seminar focused on the latest development of the dramatically changing operations research field and the application of these developments in the transportation field. For example, parallel processing and the implications for transportation related problems which often naturally decompose into parallel paths was explored in depth.

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 Lab supports all transportation subjects and the individual research and academic work of graduate and undergraduate students in transportation.

During the past year, the TCL has continued its growth. We have added two more 386-based machines and a variety of peripheral devices. On the software side we have installed Windows/3 as the standard user interface and implemented a centralized disk management set of rules.

As always, the TCL kept on top of new technologies by upgrading all its compilers, tool kits, and other programming tools as well as keeping up with the newest versions of business software (word processors, spreadsheets, database managers). In particular, our desktop publishing station has been significantly upgraded with the addition of a Mac II and hard disks for the older Mac SE machines.

SPECIAL EVENTS

The Center for Transportation Studies participated in the TransExpo exhibition in Washington, D.C., held in conjunction with the Transportation Research Board (TRB) Annual Meeting in January 1990.

At TransExpo, the CTS exhibited the solar car, Solectria V, developed by a group of students led by James Worden, a graduate student in Mechanical Engineering. This car, which has won several competitions, caught the eye of Secretary Samuel Skinner, US Department of Transportation. Mr. Skinner praised this project and the participating students in his formal remarks at the TRB Chairman's Luncheon.

The TRB meeting itself was attended by a number of MIT faculty and staff who gave professional presentations and chaired committees and formal sessions. Among those attending this major professional meeting were Professors Ben-Akiva, Henderson, Koutsopoulos, Steven Lerman, Gakenheimer, Sheffi, Sussman, Nigel Wilson, and Mr. Humphrey.

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. A broad spectrum of topics were covered by a distinguished group of speakers as follows: Mr. William K. Doggett, Vice-President of Manufacturing Materials Management, The Gillette Company; Mr. Matthew Edelman, Manager, TRANSCOM; Dr. Richard R. John, Acting Director, Transportation Systems Center, US Department of Transportation; Mr. Daniel Brand, Vice President, Charles River Associates; Professor Koutsopoulos, Department of Civil Engineering, MIT; Professor Francois Soumis, Department of Applied Mathematics, Polytechnique School, Montreal, Canada; Mr. Matthew A. Coogan, Undersecretary of Transportation and Construction, Massachusetts Executive Office of Transportation and Construction; Mr. Travis P. Dungan, Administrator, Research and Special Programs Administration, US Department of Transportation; and Professor Richard D. Thornton, Department of Electrical Engineering and Computer Science, MIT.

Summer Subjects

Last August, for the seventh 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 will be offered in July 1990 in Australia as well as on campus in August 1990.

In June, Professor de Neufville and Professor Amedeo Odoni offered, for the second time, a subject in **"Airport Systems: Strategic Planning and Detailed Design."** It once again proved 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.

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, 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 like 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:

In *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 and programming languages that yield, over a broad set of applications, cost-performance improvements of several orders of magnitude relative to single processors. This research is expected 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 *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 calling of programs in one environment from programs in another, perhaps different, environment; storage in persistent object-oriented repositories and the sharing of structured data among such programs; 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.

Taken together, these two thrusts in parallel and networked machines signal our expectation that future computer systems will consist of multiprocessors interconnected by local and long haul networks, and perhaps some day by national network infrastructures, as ubiquitous and as important as today's telephone and highway infrastructures.

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. Examples include the 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.

In our fourth category of research, *Theory*, we strive to understand and discover the fundamental forces, rules, and limits of computer science. 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 computer networks. Theory also touches on several predominantly abstract areas, like the logic of programs, the inherent complexity of computations, and the use of cryptography and randomness to 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 Voyager, a speaker independent spoken language understanding system. Voyager accepts continuous human speech and can answer queries posed to it in English sentences and phrases. It handles a dialog which clarifies incomplete query specifications, and resolves anaphoric references across a sequence of queries. Voyager has as its domain a subset of the geography between MIT and Harvard, and can answer questions about and give directions for travelling between hotels, hospitals, restaurants, banks, colleges, etc. in the domain area.

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. Professor David Tennenhouse and his colleagues have begun research on computer workstations that will include video images, just as today's workstations handle text. Novel processing-on-the-fly methods are being explored in this area, in addition to the more traditional retrieve-process-and-store techniques. We consider this area of research important because visual images are likely to be used increasingly. People are becoming more used to visual images because they can cut across linguistic barriers.

3. Professor Stephen Ward has completed a prototype of the NuMesh, a "tinker toy" system that allows for the building of special purpose computers out of general purpose, small size blocks. The resultant machines are intended to carry out special purpose processing at high speeds.

During this reporting period, the Laboratory's Distinguished Lecturer Series included presentations by John Hennessy, Bell Professor of Electrical Engineering and Computer Science, Stanford University; Terrence J. Sejnowski, Director, Computational Neurobiology Lab, Salk Institute and Professor of Biology and Physics, University of California, San Diego; Ronald L. Graham, Adjunct Director, Research, Information Sciences Division, AT&T Bell Laboratories; Robert M. Metcalfe, Ethernet Inventor and 3Com Corporation Founder; and Gordon Plotkin, Professor of Computer Science, University of Edinburgh.

Professors Leo Guibas and Mauricio Karchmer both joined the Laboratory as members of the Theory of Computation Group and Messrs. Joseph Polifroni of the Spoken Language Systems Group and Kenneth Streeter of the Information Mechanics Group became members of the research staff. Changes in the administrative staff included the departure of Mr. William Fitzgerald, who was replaced as Fiscal Officer by Ms. Azadeh Djazani, and the assignment of Ms. Carol Robinson to Personnel Officer.

Departures included Professors David Shmoys and Eva Tardos who left the Laboratory to join Cornell.

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 400 people -- 110 faculty and research staff, 40 visitors, affiliates, and postdoctoral associates, 35 support staff, 160 graduate students, and 55 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, like X Windows, and joint studies on research areas of common concern.

Technical results of our research in 1989-90 were disseminated through publications in the technical literature, through Technical Reports, numbered 426 through 479, and Technical Memoranda, numbered 407 through 432.

MICHAEL L. DERTOUZOS

Laboratory for Electromagnetic and Electronic Systems

The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 12 faculty and 11 research staff from the departments of Electrical Engineering and Computer Science and Mechanical Engineering. Disciplines represented include power electronics, automatic control, electromagnetics, continuum electromechanics, high voltage research, heat transfer, insulation research, quantitative physiology, cell biology, systems analysis, and economics. Faculty and students collaborate in projects aimed at both the practical engineering objectives of sponsors and at the underlying engineering sciences. Interactions with other laboratories is encouraged including the Energy Laboratory's Electric Utilities program.

POWER ELECTRONICS

Professors J.G. Kassakian, G.C. Verghese, and M.F. Schlecht lead the laboratory's teaching and research activities in power electronics. In addition, they continue to serve in professional society leadership roles, Professor Kassakian as a member of the Governing Board of the European Power Electronics Society, Professor Verghese as a member of the IEEE Power Electronics Society Administrative Committee, and Professor Schlecht as Technical Program Chair of the 1990 Power Electronics Specialist Conference and General Chair of the 1991 PESC to be held at MIT in June.

Their Summer Session offering, 6.335, Introduction to Power Electronics, was again a successful enterprise. This summer, a special offering is being made for professors who wish to start power electronics programs in their own universities (approximately 50).

Professors Kassakian and Schlecht have increased their involvement in manufacturing oriented endeavors. Professor Schlecht has a Junior Faculty Award from the Leaders for Manufacturing Program, and Professor Kassakian holds a Leaders for Manufacturing Professorship. They also represent the EECS Department in the new products program, a recent initiative of the ME and EECS Departments and the Sloan School. Professor Kassakian serves on the Executive Committee of this Program. Professor Schlecht serves on the R&D Committee of the Power Sources Manufacturers Association, an organization devoted to helping the fragmented power electronic industry in this country operate with more cooperation.

Work continues in the development of high frequency, high density power supplies that are highly manufacturable. Five of these power supplies, each taking 100W from a 50V input bus and delivering it to their outputs at +5V, +12V, and +3.3V, were successfully installed into a Digital Equipment computer to demonstrate their performance and space saving features. These supplies, which achieve power handling densities greater than 50W/in³, make possible distributed power supply architectures that can improve the performance and manufacturing of computers. A Leaders for Manufacturing Fellow is currently supervised by Professor Kassakian as she helps DEC incorporate these supplies into their products.

Efforts continue on the development of high frequency, highly manufacturable versions of power factor correction and 300V-50V front-end converters in the 1.5kW range needed to complete the distributed power supply system. In all of this work, reduction of EMI has become a major effort, and a great deal has been learned about how component design, circuit topology, and circuit layout influence the EMI levels.

Continuing studies by Professor Verghese and his students, directed at dynamic modeling and control of power circuits and the development of corresponding computer based tools, have led to corrections of long-standing models of switched power converters. Simple approximate models that are well suited to sampled-data control of these converters have also been developed. In addition, novel schemes to permit decoupled control design and application for multi-switch, multi-output power converters have been obtained. The program continues in close collaboration with industry.

SYSTEMS IDENTIFICATION AND CONTROL

Micromotors

Professors J.H. Lang, M. Schmidt (MTL&EECS), and S. Senturia (MTL&EECS), and their students, have continued their highly interdisciplinary and collaborative development of micron-scale motors (micromotors) machined from silicon-related materials using techniques similar to those used to fabricate integrated circuits. The past year has been extremely productive for the group. They have produced a second generation of several

different micromotors, all of which exhibit outstanding electromechanical performance. Further, they have developed a variety of dynamometry techniques that allow the study of micromotor dynamics. That study has yielded considerable insight into such phenomena as friction, wear, and windage drag of moving micron-scale mechanical components. They are also working on motion sensors for the micromotors, with the expectation of embedding the sensors into the micromotors. Closed-loop motion control will then become possible. Finally, they have begun to work on applications of the micromotors.

Motor Manufacturing

Professors Lang, J.L. Kirtley, and Dr. R.D. Tabors, together with their students have just completed the first year of a three-year project supported by the Leaders for Manufacturing Program. That project is directed at changing the manner in which market-taking manufacturers of variable-speed electric drives respond to customer requests. The product of the project will be a software design assistant that is knowledgeable about the design of variable-speed electric drives, the manufacture of those drives, and the past experience of the manufacturer. With this knowledge, the design assistant will help an engineer to design a drive optimized for electromechanical performance, manufacturability, cost, and delivery within the manufacturing constraints of the manufacturer. During the past year, the group has outlined the objectives and structure of the design assistant. Further, they have presented these results to various companies, both inside and outside of the LFM Program, and incorporated the criticism received. In general, the results have been very well received. Further, the group has begun the development of various components of the design assistant. The first is a detailed simulator of the manufacturing process capable of giving accurate estimates of drive manufacture cost and delivery time. The second is an historical data base which stores only drive designs which are dominant in terms of electromechanical performance, cost, and manufacturability. The third is a detailed motor drive design module. During the next year, these components and others yet to be developed will be assembled as the design assistant begins to take shape. The close coupling with industry will continue.

Motor Design

Professor Lang and his students have recently begun a project to develop very-high speed generator systems which exhibit very-high power densities for commercial and military aircraft. These generator systems include a generator, its power electronics and its controller. The generator is specifically a variable-reluctance generator. In addition to beginning a study of the physical behavior of such generator systems, the group is undertaking the development of computer-automated design strategies for the systems. This project is closely coupled to the project on motor manufacturing, and the two groups collaborate significantly.

Robot Motor

Professor Lang and Dr. S.D. Umans, in collaboration with McGill University continue to work on the development of an advanced robot arm. MIT is developing a new motor for the arm which will exhibit a very-high ratio of torque to mass. The motor has been designed, and the first prototype has been constructed, together with a special dynamometer facility. Testing of the new motor will begin shortly.

Motor Estimation And Control

Professor Lang and his students continue their study of the dynamics, estimation, and control of electrical machine systems. These systems include electrical machines, their power electronics, electrical and mechanical loads, and controllers. An important theme of that study is the use of the electrical machine as a sensor of itself and its environment. For example, the group has developed a variety of filters which use only voltage and current measurements taken at the terminals of a machine to provide estimates of machine (rotor) motion, machine temperature, and machine failures. This work is being extended to the estimation of similar properties of the loads. Further, the filters have been embedded in practical controllers, adaptive controllers, and failure monitoring systems. All of this work has been experimentally demonstrated. Much of it is in the process of development for use by the sponsors in commercial products.

ELECTROMECHANICS, HEAT-TRANSFER, AND CRYOGENICS

Superconducting Generator

Over the past year Professors Kirtley, J.L. Smith (ME) and Dr. Umans have discovered the source of the cooling problem and have designed a "fix". The problem can be described as a "vapor-lock". It arises from a

relatively small amount of vapor production in the helium inlet to the rotor. This vapor is not vented properly, so displaces the liquid helium in the rotor. The problem is that sufficient space for evolved vapor to leave the central parts of the rotor is not provided.

The fix to this is to provide more vent space to the rotor, and we are providing this with an additional exhaust channel, which will end in an orifice at the drive end. In addition, we are building a new thermal radiation shield. The old shield, which had a gas leak, was not sufficiently effective, and a replacement shield, while quite effective, is made of copper and therefore cannot be used in runs in which the rotor is to be excited. The new shield is designed to be used with liquid nitrogen cooling, and has enough azimuthal thermal conductivity designed in, through conductive epoxy and copper shunts, to provide a uniform temperature of about 90K.

The support situation for the superconducting generator project has changed. The project was begun with support from the Energy Research and Development Administration and was therefore grandfathered into the Department of Energy. That support ended in the fall of 1989. In January of 1990, the Electric Power Research Institute started supporting the work. The EPRI project is projected to continue until the end of 1992, at which point the machine should have been connected to the local power network and have produced real power. It is expected that changes to the rotor and the new thermal radiation shield should produce a fully working generator.

The IEEE-ASME Joint Power Generation Conference (JPGC) will be held in Boston in October. In that conference there will be a special session devoted to superconducting electric machinery. Professor Kirtley will chair that session. In response to an invitation, MIT has submitted two papers to the conference, one dealing with the experimental 10 MVA superconducting generator in general terms and the other dealing with the thermally isolating torque tubes.

United States Navy

For several years, Professor Kirtley and Dr. Umans have provided educational opportunities specific to officers of the USN who attend MIT as graduate students. This year, we are formulating a research program which will serve two purposes. First, it will result in a simulation program for electric power systems (perhaps including electric drive) on combat ships. Second, it will provide for research opportunities for naval officers attending MIT as graduate students. There is substantial interest in this field because of a new interest in electric propulsion, which shows benefits in operational flexibility, higher overall energy efficiency, survivability in combat, and the ability to divert large amounts of energy to weapons systems. Two students are working on this program at the present time, and it is expected that the number will grow, depending on who the Navy can send.

Transformer Monitoring

During the past year, research on performance monitoring of large power transformers has continued. This research, having its origins in the project Trend Analysis - Performance Monitoring of Transformers, which ran from 1984 to 1988, has evolved into several continuing research projects aimed at further advancement of the technology, and a commercial development effort. Additionally, an informal collaboration in the area of device performance monitoring has been established with Professor I.J. Perez-Arriaga of the Instituto de Investigacion Technologica (Madrid, Spain).

There has been substantial effort in the past year on Automatic Diagnosis of Transformer Failures; related current projects are Transformer Monitoring Using Vibration Analysis and A Non-Destructive Breakdown Measurement for Oil Dielectric Strength Testing.

The work on automatic diagnosis led by Mr. W.H. Hagman, has concerned the development and implementation of an on-line system of sensors, analysis hardware, and software to detect and diagnose incipient power transformer failures. It has been painfully apparent from the experience of electric utilities that traditional transformer monitoring and diagnosis techniques are inadequate, with at least two percent of large power transformers in the U.S. failing each year - at a cost of approximately one million dollars per failure. During the past year, a Master of Science thesis specifically concerned with automated transformer diagnosis has been completed by T.H. Crowley. This work involved the use of a previously-constructed experimental facility, the Pilot Transformer Test Facility in Building N-10. Experimental data was collected with the MIT Adaptive Transformer Monitoring System developed under the original transformer monitoring project. (This system automatically adapts to individual transformers through the use of mathematical models of normal transformer

operation. Anomalous conditions are detected through the repeated sensing of multiple quantities in conjunction with the recognition of long- and short-term drifts, or trends, in the condition of the transformer.) The experimental facility was used to simulate a variety of incipient failures in a 50 kVA test transformer. It was shown that the information revealed by the monitoring system is sufficiently rich to enable the diagnosis of incipient failures; furthermore, the diagnostic process can be automated to reduce the amount of diagnostic information flowing to power system control and maintenance personnel to more manageable levels.

The concepts and software developed for the adaptive monitoring system have been transferred to J.W. Harley, Inc. (Twinsburg, Ohio) for commercialization. J.W. Harley has designed the Transformer Performance Analysis System (TPAS) around the monitoring and analysis technology developed at MIT. Assistance with sensors and testing has been provided by ASEA-Brown-Boveri's Materials and Manufacturing Technology Laboratory (Sharon, Pennsylvania). At present J.W. Harley is producing the first eight Field Demonstration Units (FDU's) for installation on electric utility transformers. This sequence of basic and applied research at MIT, followed by technology transfer to vendors for commercial development has been quite successful. Current work at MIT in support of J.W. Harley is aimed at improving the adaptive capabilities of the monitoring software.

This research work has been sponsored by a variety of organizations: electric utilities, electric utility research consortia, power apparatus suppliers, and fellowships.

Non-Intrusive Load Monitoring

In this project, Professors Kirtley, L.K. Norford (Architecture), and Dr. Tabors intend to extend the work done in prior years with Professor F.C. Scheppe on residential load monitoring to commercial and industrial buildings. The problem is relatively simple with residences: there are few enough appliances that it is possible to use simple turn-on/turn-off data to both identify the appliances and to generate energy usage data for them. With larger buildings, both the number of individual loads and the diversity of those loads is increased, so the problem is more difficult. We are, with support from EPRI, attempting to attack this problem on a number of fronts: (1) By using sampling in multiple time scales, we hope to be able to see both fast and slow transients (which might arise from "soft start" devices); (2) By looking at more variables (all three phase voltages and currents, for example), we expect to see a wider range of what really happens; (3) Time harmonics may prove to be an important determining factor in discriminating between different loads; (4) Pattern recognition of load start-up transients may lead to substantial insights as to what has just started.

This project is less than one year old, and is just entering its first experimental phase.

International Conference on Electric Machines

This is the only international conference devoted entirely to electric machines. It has been held biennially since 1974, but always in Europe. For the first time it is held in the United States in 1990, and here at MIT. Roughly 300 scholars in the field of electric machinery will be here, and about 240 papers in the field will be presented. Professor Kirtley is conference chairman, Professor Lang is presenting a couple of papers, and Dr. Umans is chairing a special session on Education.

CONTINUUM ELECTROMECHANICS

An Electric Power Research Institute (EPRI) sponsored project co-supervised by Professors M. Zahn and J. R. Melcher on flow electrification in transformers has been continuing. The patent for the MIT developed Absolute Charge Sensor (ACS) was issued in Oct. 1989. The ACS is being used in testing of electrification effects in various transformer components by Cooper Power Systems and will be used on an operating transformer in tests directed by ERM. The MIT work was presented at the Public Service Electric & Gas/Electric Power Research Institute Workshop on Static Electrification in Transformers.

An ACS has also been supplied to General Motors for electrification measurements in automotive fuel systems and Ford is also considering the use of an ACS in their research. To meet industry needs in understanding the fundamental physics as well as developing laboratory measurement methods of flow electrification, we are offering an MIT Summer Session Program course (1990) entitled "Electrostatic Charging in Power Apparatus and Fuel Transfer Systems".

MIT measurements of flow electrification 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 are being installed in our flow electrification measurement facility. Moisture measurements are being correlated to new mass-transfer analysis of the transfer of moisture between paper and oil developed by graduate student P. von Guggenberg. The model describes the evolution of moisture concentrations in the paper and oil and has shown that the moisture concentration in the oil reaches an apparent steady state that is ten times faster than in the paper. This indicates that the usual measurement approach of estimating moisture content in the paper from oil moisture measurements can be in error. It also 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.

Past flow electrification theory used at MIT has implicitly assumed that the charge density of each carrier is near the equilibrium levels due to charge dissociation. However, measurements have shown that the charge densities are much greater than equilibrium levels near interfaces so that a quasi-equilibrium analysis is not valid. A more complete drift/diffusion bipolar conduction model including turbulent diffusivity and charger combination has been developed for the steady state which yields self-consistent solutions with measurements of turbulent core charge density, open circuit terminal voltage, and short circuit terminal current.

Professor Zahn has also been studying the pumping of magnetic fluids in traveling wave magnetic fields and has developed analysis that includes the effects of fluid spin fields so that fluids have internal angular momentum. Professor Zahn presented this work as an invited speaker at the Fifth International Conference on Magnetic Fluids, Riga, Latvia, USSR. He is also a member of the International Steering Committee of the Sixth International Conference on Magnetic Fluids to be held in Paris in July, 1992.

Professor Melcher and his students continue to develop parameter estimation techniques based on electric, magnetic and electromagnetic evanescent fields. Recently he was awarded a patent for sensing inhomogeneities in magnetization and conduction properties. Also, a patent has been awarded for electrically controlling the color of metallic paints.

The paper "Single-Stage AC Electrostatic Precipitation" by Ph.D. student, R.M. Ehrlich and Professor J.R. Melcher was given a Prize Paper Award by the IEEE Industrial Applications Society.

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. Similar optical measurements in highly purified water show the strong interplay on charge transport through the electrode to form oxide and the resulting change in electric field and charge density distributions as the oxide grows. An invited review paper on this work was presented by Professor Zahn at the Sixth International Symposium on High Voltage Engineering.

Dr. C.M. Cooke's research activities this past year have been centered around (1) advanced instrumentation and modelling and (2) basic insulating materials characteristics.

The instrumentation studies have been centered on three topics; ultrasound diagnostics of insulation especially the Electrically Stimulated Acoustic Waves (ESAW) method, a non-destructive breakdown measurement of oil insulation strength, and gas-in-oil measurement especially using membrane phase separation and mini fuel cell detection.

As pioneered by Dr. Cooke and Ph.D. student, J. Bernstein, the ultrasound measurement method of ESAW has provided the first opportunity to obtain, non-destructively, detailed information internal to active solid insulation structures, including high-voltage power cables. With ESAW it has been possible to observe slow charge accumulations at various temperatures and applied stresses. It has been shown that local stresses from these charges can greatly exceed the applied stresses, implying important limits to practical operation and testing of commercial cables. The ESAW work has enabled a clear understanding of major differences between dielectrics and helped to establish models for charge accumulation (with Professor S. Senturia, MTL&EECS).

Because ESAW is a new method it was carefully calibrated against known electron beam implantation of charge and against the known destructive test method of Thermally Stimulated Currents (TSC) to unambiguously demonstrate ESAW as a quantitative technique. Both results showed good correlation of ESAW. The TSC

comparison work was done jointly with Professor J. Tanaka at the University of Connecticut. A new project to apply ESAW to oil-paper insulation systems is beginning in the summer.

The non-destructive breakdown method for oil testing was developed by Dr. Cooke during the previous 5-year transformer project. A new effort on this basic method has been started by Dr. Cooke and Mr. Hagman and is focussed on establishing the stability of the test against typical variables such as oil temperature and oil flow. A new test cell installed in an oil flow loop has been constructed and is being automated so as to better demonstrate the approach for use on in-service transformers. Several utility companies have expressed an interest in trying the method on their system.

The dissolved gas-in-oil studies have been supported by a commercial company to enhance the capabilities of these measurements in field applications. The work has centered on determining and modelling causes for variations in the measurement values.

Modelling of charge accumulation in dielectrics has been greatly enhanced by the information available from the ESAW studies. A new 'virtual cathode' technique was used to create a cathode-less electric stress in a dielectric and hence to enable the distinction of charge injection and conduction processes. Charge accumulation versus time further allows the measurements to provide information on conduction activation energies and equilibrium concentrations of charge traps. The ESAW results are also providing results which allow the modelling of charge injection and effects from electrodes and internal interfaces. Overall a whole new understanding of the dielectric characteristics of materials is being opened by the knowledge of what actually occurs inside the dielectric.

BIOLOGICAL ELECTROMECHANICS AND PHYSIOLOGY

Professor A.J. 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 and the Shriners' Hospital, Tampa. Experiments using cartilage specimens in organ culture have shown that high amplitude static and low frequency compression can cause degeneration and loss of matrix constituents in a manner that may help to define the threshold of abnormal joint loading. Higher frequency compression can increase synthesis of cartilage tissue in frequency ranges that are of therapeutic interest. New initiatives are aimed at identifying mechanisms by which pressure, fluid flow, cell deformation, and other physical factors may modulate cellular synthesis of growth factors and cytokines, with the goal of understanding osteoarthritic diseases. This year, Professor Grodzinsky is chairman of the Gordon Research Conference on Bioengineering and Orthopaedic Sciences, which focuses cellular response to physical stimulation.

A recent initiative and patent application have focused on the experimental and theoretical demonstration of a surface probe for nondestructive detection of cartilage degeneration that occurs at the earliest stages of osteoarthritis (OA). This probe consists of an interdigitated electrode/strain gauge array capable of detecting electrokinetic transduction signals that are characteristic of normal cartilage. By varying the spatial wavelength and frequency of an applied current at the cartilage surface of an intact joint, the signature of the resulting mechanical surface stress may quantify local tissue changes associated with OA degeneration. Progress to date has confirmed the feasibility of the approach; current studies focus on sensitivity of the probe.

Research continues on culture of cartilage cells in agarose gel. This system results in a mechanically functional cartilage-like tissue during 4-8 weeks in culture, and is now being used to study mechanisms by which connective tissue cells respond to physiological loading forces at the intracellular and molecular levels. A new collaboration with the Mueller Institute in Switzerland is aimed at quantifying morphological changes at the cell and matrix level when agarose/chondrocyte cultures are subjected to mechanical loading forces.

Professor Grodzinsky's group is also continuing research on electrically controlled membranes for protein separations and feedback-regulated drug delivery. Recent publications and presentations at AIChE and Controlled Release Society meetings have documented the mechanical and electrochemical rate processes that determine the kinetics of electrical controlled swelling of hydrogel membranes. The use of electrophoretic and electro-osmotic augmentation of transport in gel-immobilized cell culture is a new application of these processes in biotechnology now being explored.

Professor M.L. Gray's research focus continues to be directed towards the evaluation of the role of physical forces in connective tissue growth and development. Over the past year we have characterized the growth (i.e., change in tissue dimensions) of neonatal rat mandibular condyles in vitro, over a 5 week period under

non-loaded conditions. We have developed a system in which controlled static compressive loads can be applied while continuously monitoring tissue length. Studies investigating the relationship between growth, tissue composition, and applied load will be initiated this summer. In addition, we have recently established a collaboration with researchers at Children's Hospital Medical Center who have interest and experience in studying gene expression in developing skeletal tissues. This collaboration will provide additional information regarding cell activity under load, and should also provide us with in vivo development data for comparison.

In collaboration with co-workers at Beth Israel Hospital, we continue to develop nondestructive techniques using NMR spectroscopy and imaging for evaluating tissue composition and functional integrity. We have made substantial progress in estimating tissue fixed charge density from sodium and proton NMR spectra of articular cartilage specimens. Over the long run, the capability of non-destructive assessment of cartilage integrity will greatly enhance our ability to evaluate cartilage under physiological and pathophysiological conditions.

We have also been working together with the Microfabrication Group of MTL (Professor Senturia in particular) towards the development of micromachined devices for medical and biological applications. We have nearly completed the development of a microfabricated optical flow cytometer. This is one of potentially many instances in which fluid channels, optical sensors, and perhaps pumps and valves can be constructed in an integrated fashion to provide a sensing system on the small size scales so typical of biological systems.

UTILITY SYSTEM PLANNING AND OPERATION

In the Fall of 1989, Dr. M. Ilic accepted an appointment as a Senior Research Engineer in the Department of EECS. Her research in electric power systems as a permanent member of the MIT community was initiated by the "MIT Workshop on Research Needs in Power Systems" to establish future needs and directions for power systems research at MIT. Utilities from all over the country participated. In cooperation with the Energy Laboratory's Electric Utilities Program, it is planned to hold such a workshop on an annual basis.

The New England utilities sponsored project on "Development of Smart Algorithms for Voltage Monitoring and Control" is in its second phase. Dr. Ilic and her students have demonstrated its feasibility on the actual data representing the New England system. W. Stobart, who has finished his Master's Degree thesis on this project, is presently working with an outside vendor (Power Technologies, Inc.) on a production-grade version of this method. It is quite rare to follow the entire path from the theoretical developments to the useful software, and we are quite proud of this development.

A sequence of two graduate courses in the EECS Department has been approved to start in the Fall of 1990. The course topic is Advanced Power Systems I and II, and it will be taught by Dr. Ilic. This is viewed as the first step in building a basis for stronger momentum in the direction of electric power systems research.

Since his return to MIT after serving as the Director of the International Institute for Applied Systems Analysis (IIASA) for three years, Professor Lee has also spent a significant amount of his effort on new educational programs offered jointly by the School of Engineering and School of Management. He served as the Faculty co-chairman of the Management of Technology Program and for the Leaders for Manufacturing Program, as a member of the Operating Committee, and the Chairman of the Pro-seminar Committee. For the latter responsibility, he invited Professor S. Shiba, a renowned expert on Total Quality Management (TQM) in Japan to give two series of lectures on TQM to LFM students and persuaded Professor Shiba to come to MIT for seven months as a visiting professor to introduce TQM as a course for MIT faculty and students.

It has been generally recognized that there are two deficiencies in the U.S. effort on total quality management:

- No educational courses in universities.
- No network learning among corporations.

In addition to the activities of Professor Shiba, he also organized a Center for Quality Management (CQM) with seven major corporations in this area. Two members from MIT participated in a five week extensive planning effort for that seminar which included a trip to Japan. It is the hope that this effort will be an important step forward in correcting the two deficiencies, including a new educational activity at MIT on TQM.

With Harvard Business School Press, Professor T.H. Lee, Mr. B.C. Ball and Dr. Tabors have published the book Energy Aftermath.

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 Gerald L. Wilson. 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.

Thirty-one faculty members, four 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, Bell Communications Research, Inc., NYNEX, the Army Research Office, GTE, IBM, General Electric, the C.S. Draper Laboratory, the Office of Naval Research, Data General, the Air Force Office of Scientific Research, and the National Institutes of Health.

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 computer science in the 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

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.

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 Professors Alan Willsky and Sanjoy Mitter and Dr. Peter Doerschuk is ongoing.

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 through the research community and funding agencies, lead us to believe that this will be an extremely fruitful area for some years to come.

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.

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.

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. Among the visitors this year were: Dr. Ofer Zeitouni, Technion, Israel; and Professor Michael Miller, Washington University, St. Louis, among others. In addition, General Maxwell R. Thurman, Commander, Army Training and Doctrine Command (TRADOC), visited the Center in June 1989 to discuss current research efforts in the areas of control, communications, robotics and vision with Center faculty.

Speakers in the 1989/90 CICS Colloquium Series included: Eugene Wong, University of California at Berkeley; Nicolas Surlas, Ecole Normale Supérieure, Paris; Bernard Gaveau, University of Paris VI; and Stephane Mallat, New York University. Two workshops and a series of tutorials were organized by CICS Faculty: Some Modern Applications of Mathematics (Five Tutorials), November 1989; the Workshop on Speech Processing and Recognition, January 1990; and the Workshop on Global Models for Image Analysis, May 1990.

An external peer review of CICS was conducted by the Army Research Office (ARO) in March 1989. The Review Committee was headed by Avner Friedman, Director, Institute for Mathematics and its Applications. Other members of the review team were: John Blair, Director of Research, Raytheon; P.R. Kumar, Director, Coordinated Science Laboratory, University of Illinois; Eugene Wong, Chairman, Department of Electrical Engineering and Computer Sciences, University of California at Berkeley; Alain Bensoussan, INRIA, France; S.R.S. Varadhan, Courant Institute of Mathematical Sciences, New York University; and George Zames, Department of Electrical Engineering, McGill University. The Committee was greatly impressed with what has been achieved since the establishment of the Center and reported back to ARO in a very positive fashion.

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, H. Austin Spang III, 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.

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, Robert Kennedy, and Robert Kingston are conducting this research which includes theoretical and experimental components.

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.

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.

Information Transfer and Retrieval

Research on information transfer and retrieval focuses on investigating issues concerning the way computer-based information systems can be engaged more easily and effectively by potential human users.

Several current projects center on analytical and experimental investigations of expert computerized intermediary systems to assist users in accessing and operating heterogeneous bibliographic database and retrieval systems. Staff members who have supervised these efforts include Mr. Richard S. Marcus and Professor J. Francis Reintjes. An expert intermediary has been designed and partially implemented which should help make searching a quantified science rather than an informal art through such techniques as automatic (1) ranking by estimated relevance of documents in Boolean Searches, (2) recall estimation, and (3) search strategy reformulation based on user relevance feedback.

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.

HIGHLIGHTS

Professor Dimitri Bertsekas was invited to give a plenary talk at the 28th IEEE Conference on Decision and Control in December 1989. He spoke on "Communication Issues in Parallel Computation."

Professor Roger Brockett, Associate Director of CICS and An Wang Professor of Engineering and Computer Science at Harvard University, has been awarded the 1989 Richard E. Bellman Control Heritage Award by the American Automatic Control Council.

A paper by Professor Munther Dahleh and Professor J.B. Pearson of Rice University has been selected to receive the prestigious George Axelby Best Paper Award for a paper published in the *IEEE Transactions on Automatic Control*.

Professor Robert Gallager has been awarded the 1990 IEEE Medal of Honor. This is the most prestigious of the many awards made by IEEE and recognizes Professor Gallager's "clearly exceptional addition to the science and technology of concern to IEEE."

Professor Sanjoy Mitter was invited to give the plenary talk "Some mathematical problems in machine vision" at the Venice-1/Symposium on Applied and Industrial Mathematics in October 1989.

LIDS graduate student Cuneyt Ozveren was a finalist in the 1989 CDC Best Paper Award Student Competition for the paper "Output Stability of Discrete Event Dynamic Systems" co-authored with Professor Alan S. Willsky at the 28th IEEE CDC.

CICS faculty member Ronald L. Rivest has been elected to the National Academy of Engineering for contributions in cryptography and theoretical computer science. Professor Rivest is Professor of Electrical Engineering and Associate Director, Laboratory for Computer Science at MIT.

Professor Gunter Stein has won the Control Systems Society's Bode Prize for 1989. He delivered the Bode Lecture, "Respect the Unstable," at the IEEE Conference on Decision and Control in December 1989.

ROBERT G. GALLAGER
SANJOY K. MITTER

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 develop a scientific foundation for manufacturing. Currently, 20 faculty members, 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 a focus on processes. Rather than developing better methods of coping with complex manufacturing systems, our goal is to reduce the systems' inherent complexity through improved understanding of processes and systems. This approach enables us to blend basic research with 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 are playing a major role in the Leaders for Manufacturing Program. Curriculum development is extremely important, as 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 Gerald L. Wilson. David Hardt, Associate Professor of Mechanical Engineering, serves as Director, Dr. Andre Sharon serves as Associate Director, and Ms. Sally Stiffler serves as Assistant Director for Administration and the Collegium.

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 Intelligent Manufacturing Program, the Knowledge Systems Program, and the Microcellular Plastics Program. Further technology transfer is facilitated by the LMP Industrial Collegium, presently comprised of over 35 companies with a common interest in manufacturing. The collegium serves as an information channel between industry and the LMP.

CURRENT RESEARCH

Research activities in the LMP encompass the following areas:

- Process Innovation
- Design/Manufacturing Integration
- Tribology
- Scheduling and Production Planning
- Flexible Automation and Robotics

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, microcellular plastics, and laser machining.

Tribology

Tribology, or the study of wear, is providing a better understanding of wear mechanisms, which in turn will lead 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 and Robotics

Flexible automation facilitates small-batch manufacturing, which will very likely be the standard mode of operation in the future. Industrial robots are central to flexible automation, but current technology severely restricts their use in manufacturing. It is our goal to extend the capabilities of robots through novel hardware, software, and control strategies. Direct-drive robots and macro/micro manipulators are among the robot architectures studied in the Lab.

We are also investigating other issues in flexible automation, including planning, reconfigurable fixtures, sensors, reconfigurable die-surfaces for metal forming, and off-line programming.

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.

NEW APPOINTMENTS

Dr. Jung-Hoon Chun, Assistant Professor of Mechanical Engineering, joined the faculty of the Department of Mechanical Engineering at MIT in 1989. Professor Chun teaches a subject in manufacturing processes, and is involved in integrating new manufacturing subjects into the graduate curriculum. He conducts research in materials processing and manufacturing, particularly in the area of metal-matrix composites. He has recently initiated research on the near-net shape manufacturing of metal-matrix composites via the spray forming process and the composite injection molding process.

NEW INITIATIVES

In 1989, the NSF announced an initiative for advancing the technology frontiers and knowledge base in manufacturing through major innovations in generic engineering science approaches. The Strategic Manufacturing Initiative (SMI) is intended to foster new approaches to the solution of important problems in design, manufacturing information processing, and manufacturing technologies through interdisciplinary collaborative research.

Two LMP faculty members, Professor George Chryssolouris and Professor Emanuel Sachs, received two of the ten SMI grants awarded nationwide.

Professor Chryssolouris and Professors Stephen Graves and Karl Ulrich, both of the Sloan School of Management, are collaborating on a project entitled "Decision Making in Manufacturing Systems," which seeks to improve the performance of manufacturing systems along the dimensions of product quality, product cost, and lead time. In addressing these goals the research focuses on three areas of the manufacturing system: **product design, production planning, and process control**. The research initiative also incorporates three disciplinary approaches: manufacturing engineering, operations research, and artificial intelligence.

Professor Sachs, Professor Michael Cima, of Materials Science and Engineering, and Dr. James Cornie, of the Materials Processing Center, were also awarded a grant for their project "Three Dimensional Printing." Three Dimensional Printing is a process for the manufacture of tooling and functional prototype parts directly from computer models. Powdered material is deposited in layers and the powder is selectively bound by "ink-jet" printing of a

binder material. Following the sequential application of layers, the unbound powder is removed, resulting in a complex three-dimensional part.

DAVID E. HARDT
ANDRE SHARON

Leaders for Manufacturing Program

The essence of the Leaders for Manufacturing (LFM) Program can be summarized in three words: people, principles, and partners. The *people* include company leaders and practitioners, faculty, and students. The *principles* are those now guiding the current best practice and those that emerge as new paradigms for future manufacturing. The *partnership* is tripartite, consisting of industry and MIT's Schools of Engineering and Management.

The program was begun as a five-year experimental educational/research partnership between 11 major U.S. manufacturing firms and MIT's Schools of Engineering and Management. Its overall goals are to discover and codify guiding principles for manufacturing, and educate future leaders for manufacturing firms. The program adopts a broad definition of manufacturing, including product and process development through production, sales, and service, and emphasizes the importance of integration.

Launched in the spring of 1988, the Leaders Program draws on more than five years of research and discussion among industry leaders and MIT faculty. The program responds to an increasing number of questions posed by American manufacturers about how to improve productivity and compete globally. It begins to address issues for improving American industrial performance that were raised by the MIT Commission on Industrial Productivity during the Commission's two-year study of eight American manufacturing industries in a global market.

Stated goals are to attract outstanding talent to discover principles governing world-class manufacturing, incorporate these into curricular materials, and with these resources, attract and prepare exceptional young people for leadership roles in American manufacturing firms and otherwise assist in the governing principles' incorporation into manufacturing practice. To achieve these goals, the program must begin to restructure the academic and industrial environments, refurbish manufacturing's tarnished image, and forge new relationships within and between universities and industry, management and engineering. The program's Operating Committee has proposed that the Leaders Program can achieve its major goals by generating eight "products." The remainder of this report is organized around these eight products.

GRADUATE TRAINING, PLACEMENT, AND SUPPORT

Curricula

The Leaders Program seeks to build an identifiable, comprehensive manufacturing curriculum that differs significantly from current models, by experimenting and taking risks. The program draws on MIT's strengths in engineering and management to teach Leaders students the fundamentals of both technology and manufacturing management. It aims to provide students with integrative experiences, teach them how to lead and effect change, and instill in them an appreciation for continuous incremental improvement as well as groundbreaking, innovative improvement — and the total manufacturing enterprise's responsibility in producing both.

The key educational component of the program is the Fellows Program: a two-year graduate experience integrating management and engineering, including a six-month internship at a sponsor company's plant site. Students participating in this segment of the program receive fellowships to gain valuable experience working on major issues of interest to both MIT and participating companies while earning two master's degrees, one in management and one in engineering. The 6.430J/3.81J/15.064J Engineering Probability and Statistics course was specially designed for the Leaders Fellows; the MIT Sloan School of Management is offering Fellows such custom courses as 15.961 Total Quality Management, 15.966 Leadership and Organizational Change, and 15.066J/3.83J/2.851J System Optimization and Analysis.

The Leaders Program benefits students in other educational programs at MIT, as well, enhancing their traditional degrees with the broader perspective offered by manufacturing research. The program has brought industrial expertise to the classroom in the form of seminar leaders, laboratory section teachers, and lecturers (e.g., for 2.73 Design Projects). In addition, faculty have incorporated issues gleaned from Leaders projects and classes into existing courses; subjects influenced by the Leaders Program include 2.870 Development Process for Products and Manufacturing, 3.555 Materials Selection and Design, 15.763 Practice of Operations Management, and 15.769 Manufacturing Policy.

Entirely new courses are also being developed for students not formally affiliated with the Leaders Program, acquainting them with manufacturing issues. Four Leaders faculty at the Sloan School developed the 15.970 Management & Technology Module, introduced this past year, to integrate technology with management; the course was required of all first-year Sloan master's degree candidates on the basis that managers in today's manufacturing firms must understand the technologies driving their industry to make wise decisions. Other new subjects that are being developed partly as a result of the Leaders Program for other students besides the Leaders Fellows include 15.363 Managing Technological Change in Manufacturing (already introduced), and, coming up in the School of Engineering, a new course in applied statistics for engineers.

Graduates

The Leaders Program seeks to attract some of the nation's most capable, farseeing young people to the challenging, multidisciplinary field of manufacturing. This past year, 191 people applied to the Fellows Program, compared to 120 applicants during the prior year. Forty-three were accepted, and 35 ultimately chose to join the program.

This past year saw the Leaders Program's first graduates in the 24 students who participated in the program's on-site research internships. Among these, the graduating Leaders Fellows organized an alumni association, assigning members to participate in the program's Operating Committee meetings held four times yearly, gather and distribute alumni working papers, and assist the program with student recruiting, among other supportive activities.

The second class of 32 Leaders Fellows is now working on their internship research projects, and a third class of 35 Fellows has begun the program coursework.

Aside from the Fellows, the Leaders Program also fully or partially supports a large group of research assistants earning master's degrees or doctorates through manufacturing-related research — 66 such students in the last two years.

Careers

The Leaders Program aims to develop career paths in manufacturing that are financially competitive and intellectually challenging, and that provide opportunities to lead and effect change. The program seeks to place all graduating Fellows in companies within the manufacturing industry. Of the first graduating class, 45% assumed jobs within the LFM partner firms and 20% joined other manufacturing firms; 35% accepted positions with consulting firms, primarily in their manufacturing practices. The Leaders Program expects that all of the Fellows graduates will ultimately assume positions in manufacturing companies; the program is continuing to work with the companies to improve recruiting strategies, methods, and career opportunities in manufacturing.

The program seeks, in addition, to create a cohort of role models and influential alumni, develop a mentoring system that includes company people and faculty, and create values and methods by which graduates mentor students.

COLLABORATIVE PROCESSES AND MODES OF OPERATION

Collaboration

The Leaders Program aims to create structures and incentives for meaningful collaboration among participants to achieve its broad goals. Five departments in MIT's School of Engineering — Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, and Mechanical Engineering — are cooperating with the School of Management and 11 firms. One hundred industrial practitioners are currently working in the program with more than 50 MIT faculty, 67 Fellows, and approximately 60 graduate research assistants. Nineteen senior faculty, awarded Leaders for Manufacturing professorships, also serve as liaison faculty to the 11 partner firms.

In the past two years, faculty have made more than 180 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 co-supervise the students' internship projects; in addition, they have sent people to spend an average total of 100 man days visiting the MIT campus through the Leaders Program (based on company responses to a program questionnaire). As one notable example of corporate commitment to the program in this latter respect, Digital Equipment Corporation, from the beginning of its involvement with the Leaders Program, assigned Dr. Douglas Braithwaite, its program manager of research for manufacturing leadership, to spend substantial time on campus fostering interactions between MIT faculty and Digital Equipment people.

Manufacturing Faculty

The Leaders Program is well along in the process of building a faculty whose members not only exhibit strong disciplinary bases, but also willingly collaborate in discovering and verifying new manufacturing principles. The program has awarded term chairs to 19 senior faculty, and offered unrestricted research grants to 16 junior faculty (two of whom won the National Science Foundation's Presidential Young Investigator Award this year). Additional expertise has been gained with the appointments of Donald Ephlin (former international vice president of the UAW) as a senior lecturer, and Donald Davis (former chief executive officer of Stanley Works) as a guest of the Institute.

Continuous Improvement

The LFM Operating Committee has specified continuous improvement as a way of life in all Leaders activities. To gauge the program's progress and impact to facilitate its further improvement, the program directors organized a biennial review at which members of the Operating Committee offered examples of the program's impact on the way they conduct business; members of the faculty also described their Leaders-related research and teaching, and how this has affected the Institute and the partner companies.

The program plans to establish measurement systems to evaluate its success in achieving the eight specified products, and to benchmark itself against the best existing programs in academia and industry that have been established to improve manufacturing productivity and competitiveness.

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

fosters 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 program's 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, unrestricted junior faculty research, and theme-based, multidisciplinary research. Together, these research opportunities involve approximately 50 Institute faculty members.

The Fellows' projects, each conducted primarily during six months of work at an industrial site, offer program participants a broad exposure to manufacturing needs. Student teams, supervised by faculty and industry associates, address issues that have been identified through collaboration between the Leaders faculty and the partner firms 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 have also leveraged their involvement in the Leaders Program to conduct research collaboratively with other LFM partner companies. Digital Equipment Corporation and Motorola, for example, initiated a project last year stemming from their customer/supplier relationship and based on a new product introduction, involving four Fellows (two working within each company). This year, Digital Equipment and Boeing are conducting a joint project involving two Fellows, to help introduce a new manufacturing system employing DEC hardware and software at Boeing.

Fellows are currently addressing such topics as resource allocation practices for manufacturing process research and development; process control and benchmarking; manufacturing cost estimation and assembly cost reduction; scheduling and reliability in factory control systems; lead-time reduction; flexible manufacturing system evaluation; product performance modeling and decision support systems for design for manufacturing; and measurement and incentive systems for continuously improving product development.

The six-month 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. Currently, the program funds 30 such projects in support of the 1990 themes: design for manufacturability, manufacturing for innovation, and operations.

The Leaders Program also offers grants for unrestricted research to its junior faculty. Through these grants, the program during the past year supported the equivalent of ten full-time research assistants investigating a broad range of topics. One project investigates manufacturing scheduling as the dynamic and stochastic phenomenon it is rather than as a static problem, as it is so often portrayed as being in the technical literature. Another project investigated three-dimensional printing for rapid prototyping of parts directly from computer models; this research has grown substantially, and is now being funded only partially through the Leaders Program.

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 U.S. firms; MIT faculty, students, and administration; other universities; and the U.S. government) — especially to help its partner companies assimilate the program's products and change their manufacturing practices accordingly.

The Leaders Program hopes in these ways to magnify its impact, influencing other universities and companies to institute or join programs similar to LFM or re-direct existing programs, ideally serving as a pioneer, role model, and information source — offering direction and advice as well as the curricular materials developed. A number of other companies and universities have been making inquiries to the Leaders Program with the expressed intent of implementing similar efforts.

To communicate the results of its research to interested participants, the program is initiating a series of working papers; 100 candidate working papers (including these of students who participated in the on-site internships) were submitted to the program office this year.

Leaders faculty have characterized the program as being, in many respects, "countercultural." Evidence of this was apparent at a Leaders faculty retreat this past spring, at which participating faculty suggested the value not only of reporting the technicalities of their research through traditional channels (provided by professional conferences and literature), but also of framing their work and its results in a manner that is interesting, relevant, and appealing to the general public, thereby more effectively communicating its significance to the broader community.

H. KENT BOWEN
STEPHEN C. GRAVES

Materials Processing Center

The Materials Processing Center (MPC) provides both an interdepartmental focus on materials processing research at MIT and an international forum for the scientific information and technology transfer necessary to advance materials processing technologies. Founded in 1980 with a NASA grant to establish a research base in materials processing, the MPC has rapidly expanded to a current annual research budget of \$7.7 million. NASA still provides about 9 percent of the MPC's total budget, with another 30 percent provided directly by industry and 61 percent from other government agencies.

As an interdepartment center, the MPC reports to the Dean of the School of Engineering, Professor Gerald L. Wilson. The Director of the center is Ronald M. Latanision, Professor of Materials Science. The Associate Director is Dr. George B. Kenney.

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.

MPC research covers a broad range of materials and processes, and it emphasizes the establishment of a materials processing science base. Projects have both practical and fundamental significance, with many relating the calculated results of mathematical models to the measured results of laboratory experiments. Simultaneously, MPC research explores the fundamental economics of materials processing, competition, and substitution on a corporate, industrial, and international scale.

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: BEYOND THE TRADITIONAL

One MPC goal is 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.

High School Outreach Program

Over the past year, the MPC 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 500 students and their teachers have visited MIT to tour the materials processing research labs. The program now includes a specific one-day tour for the Boston/Cambridge-based Massachusetts Pre-Engineering Program (MASSPEP) for black, hispanic, and American Indian high school students. 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 Pre-College Teachers

An exciting new program, the MIT Special Science and Engineering Program for Pre-College Teachers, has grown out of the high school tours. While student visits to MIT serve an important purpose, the MPC believes that it is the teachers themselves who are the key to catalyzing student interest and enthusiasm for science. Students continually flow through the academic system, but the teachers who are the alumni of this program are a constant, perennial resource for their students and schools. This past June marked the program's second year. Fifty high school teachers from the New England states attended the intensive one-week program. During this week, they 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. After meeting last November, NEST members have been developing the recommendations and actions necessary to reverse the existing decline in science literacy and engineering enrollment in the United States. They are searching for a lasting solution. The MPC considers the grassroots phenomenon initiated by this committed group of science educators to be an important first step.

Fellowships and Summer Scholarships

The MPC, through its Collegium, has sponsored 54 graduate student fellowships and 40 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 1990, the MPC awarded five summer scholarships to sophomores and juniors enrolled in physics, chemistry, chemical engineering, electrical engineering, and mathematics in universities throughout North America. During the summer, these undergraduates participate in ongoing 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 90/91 academic year, the MPC offered five fellowships to students in the Departments of Materials Science and Engineering, Chemical

Engineering, and Electrical Engineering and Computer Science, and the Program in Polymer Science and Technology.

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 MPC has encouraged a close working relationship with industry through its industrial advisory board, industry collegium, and multi-client research consortia. The board, which has 25 members (24 from US industry and government and one from a foreign company), 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 MPC 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 two years, the MPC 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. This latter function is very important, given that the majority of all research and development efforts are now conducted overseas.

The MPC adopted the consortia, or multi-client sponsored research concept, in 1980 to promote collaborative, generic materials processing research. There are now four such programs: the Metal and Ceramic Matrix Composites Laboratory, the Materials Systems Laboratory, the Mathematical Modeling Laboratory, and the Resistance Welding of Automotive Steels. Through groups such as these, the MPC strengthens the link between basic research at the university and innovation in industry.

TIMELY INFORMATION EXCHANGE

Each year, the MPC hosts several symposia, each covering an area of ongoing research in materials processing at MIT, for the benefit of the Collegium member companies. The major rewards of the seminars are the timely dissemination of research results and the ensuing exchanges between speakers, MPC staff, and attending industrial representatives. These symposia also provide an opportunity for graduate students to become acquainted with practicing engineers and scientists from industry. Symposia held last year dealt with "Theory-Assisted Materials Development," "Research Trends in Surface Treatment in Japan" (in cooperation with Osaka University, Japan), "Advanced Organic Coatings for Packaging of Electronic, Magnetic, and Optical Devices: Structure, Properties, and Performance" (in cooperation with MIT's Microsystems Technology Laboratories and the Program in Polymer Science and Technology), "Present and Future Materials Processing" (in cooperation with Osaka University, Japan), "Mathematical Modeling of Materials Processing Operations," and "Multifunctional Polymers (in cooperation with MIT's Industrial Liaison Program).

The MPC, through its direct interaction with industrial personnel, promotes the technology transfer upon which innovation in materials processing is based. For the past ten years, the MPC 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 curriculum reform, affirmative action, fund-raising, 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 major curricular activity continues to be the implementation of the HASS-Distribution system, which was first introduced in the fall of 1988. In 1989-90, there were 64 subjects offered in the HASS-D system and, in 1990-91, there will be 68 subjects offered. Nearly 40 percent of these subjects have been newly introduced into the HASS-Distribution system in the last three years. A recent and important adjustment to the system is the Language Option. After considerable discussion, the HASS-D Overview Committee recommended to the Dean of the School, the Committee on Curricula, and the Committee on the Undergraduate Program that all Language IV distribution subjects be removed from the HASS-D system beginning in 1990-91, but that students be permitted to substitute either a Language III or a Language IV subject for one of their three required distribution subjects. The establishment of the Language Option resolves the vexing problem of whether language subjects belong in the HASS-D system and, at the same time, it should remove certain structural impediments that have discouraged a significant number of undergraduates from pursuing the study of foreign languages at MIT, which has no language entrance or language exit requirements.

The HASS Minor, an intermediate option between the required HASS concentration of three or four subjects in a given field and the HASS major (which typically requires 12 subjects in a given field), was introduced alongside the HASS-Distribution system in 1988-89. It is proving to be very popular. By the end of 1989-90, 352 students were registered as candidates for a Minor in one of 17 available Minor programs in the School of Humanities and Social Science and in the School of Architecture and Planning. Ninety-seven students graduated with a HASS Minor in June 1990. Two new Minors will be introduced in 1990-91: Film and Media Studies and the History of Art and Architecture, bringing the total number of Minor programs to nineteen.

For the first time in the history of the Humanities at MIT, Course XXI majors graduated in June 1990 with degrees that designated their specific fields. This is the result of the MIT faculty vote in spring 1989 that changed the designation of the degree in Humanities from the general formulation of Course XXI: Humanities to the specific formulation of the fields within the Humanities (e.g. Course XXI: History). This change is consistent with the increasing intellectual and scholarly strength of the programs within the Humanities and recognizes their growing importance in the MIT curriculum. Meanwhile, the number of undergraduate majors in Economics (111) and Political Science (54) continues to grow, a result, in part, of the changes in undergraduate admissions over the last several years. The number of undergraduate majors in Course XXI (87), on the other hand, has dipped as Minors become an increasingly popular option.

New Initiatives

The School of Humanities and Social Science has been directly involved in three new initiatives that may bear fruit in the coming year. First, every effort is being made to bring the Dibner Institute for the Study of the History of Science and Technology and the Burndy Library to the MIT campus. The combination of the new but already excellent Ph.D. program in the History and Social Study of Science and Technology and the Dibner Institute

should make MIT the world's leading center for the study of the history of science and technology.

Second, the Dean's Office, with the support of the Provost, has sponsored an initiative undertaken by faculty in Literature, Writing, and Foreign Languages and Literatures to establish in the Humanities a multidisciplinary project in cultural studies that is intended to produce a new synergism in the Humanities at the post-undergraduate level. A major conference in the fall of 1990 on the cultural dynamics of epidemics, past and present, will launch the cultural studies initiative.

Third, the School of Humanities and Social Science and the School of Management are undertaking to develop a master's degree in Management and Regional Studies. Both Schools view this initiative as part of ongoing efforts to strengthen and highlight international studies at the Institute. Committees have been established to design appropriate degree programs in two areas: Asian studies and European studies.

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 32 women faculty, which represents 22 percent of the total. Of these, 22 are tenured (19 percent of the tenured faculty). Over the past four years, the total number of women faculty has remained essentially constant.

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. The School is committed to increasing the number of minority faculty members. To this end, the departments and sections within the School have been informed that no search plan (including plans for short-term appointments) may go forward 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. The Literature Faculty conducted an intensive search this year that resulted in the offer of an appointment to a leading woman scholar of Afro-American literature who elected to go elsewhere. Although the yield from these activities has been rather discouraging in recent years, renewed initiatives in this critical area will be undertaken in the coming year.

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: Professor John Harbison of the Music and Theater Arts Section received the MacArthur Award, bringing the total number of MacArthur Award recipients in the School to four. Professor Kenneth Hale of the Linguistics and Philosophy Department was elected to the National Academy of Sciences. Professor Olivier Blanchard of the Economics Department was elected to the American Academy of Arts and Sciences. Institute Professor Noam Chomsky of the Linguistics and Philosophy Department was made an Honorary Fellow of the Royal Anthropological Institute of Great Britain and Ireland and an Honorary Member of the Gesellschaft fur Sprachwissenschaft of West Germany. Professor Rudiger Dornbusch of the Economics Department was made an honorary professor at the Universidad del Pacifico. Professor Drew Fudenberg of the Economics Department received a Guggenheim Fellowship. Assistant Professor Deborah Fitzgerald of the Science, Technology, and Society Program received a National Science Foundation Fellowship. Associate Professor Peter C. Perdue of the History Faculty received an American Council of Learned Societies Fellowship.

Assistant Professor David Brink received a resident fellowship at the Center for Advanced Study in the Behavioral Sciences in Stanford. Assistant Professor Michael Hardimon received a Ford Foundation Post-doctoral Fellowship for Minorities. Associate Professor Charles Stewart, III of the Political Science Department was made a National Fellow of the Hoover Institution at Stanford. Book and manuscript prizes went to Associate Professor Edward Turk of Foreign Languages and Literatures for his recent book (Theater Library Association prize) and to Assistant Professor Douglas Forsyth of the History Faculty for his unpublished dissertation in Italian history (American Historical Association). Honorary degrees were awarded to two members of the Economics Department: Institute Professor Robert Solow (Boston College, Colgate University, Dartmouth College, and the University of Helsinki) and Professor Jean Tirole (Universite Libre de Bruxelles). Professor Hayward Alker of the Political Science Department was elected Vice-President of the International Studies Association. In 1990-91, Professor Pauline Maier of the History Faculty will become William R. Kenan Professor of American Cultural History; Professor Charles Sabel of the Political Science Department will become Ford International Professor of Political Science; and Assistant Professor Robert Gibbons will become Pentti J. Kouri Career Development Associate Professor; he was also named an Alfred P. Sloan Research Fellow. Associate Professor Joshua Cohen of the Linguistics and Philosophy Department and the Political Science Department is the first recipient of the School of Humanities and Social Science's Levitan Prize in the Humanities. Professor Lucian Pye of the Political Science Department received the Graduate Student Council Teaching Award. The Film and Media Studies program received MIT's Sizer Award for the most significant improvement to MIT education.

Fundraising

The School continued to develop its role in fundraising and, more specifically, in the Capital Campaign effort. Because the School has relatively few alumni, efforts are being made to identify those graduates of MIT's other Schools who have an interest in the humanities and social sciences. One such person is James Levitan '45 CH, who recently gave the School a gift of \$250,000 to establish the Ruth and James Levitan Prize. Cultivational events with alumni and friends of the School and involving members of the faculty were undertaken in Boston, New York, and California. A number of these events are scheduled for the coming year. Considerable efforts have been spent on raising funds for the Paul A. Samuelson Chair in Economics and on the Ithiel Pool Memorial Fund in Political Science. The MIT Japan Program received major support from the Starr Foundation. And the Knight Science Journalism program successfully made the first of the five required matches for the Knight Foundation challenge grant. The MacArthur Foundation made a substantial award to Science, Technology & Society for a series of workshops which will bring Soviet and American scholars together to discuss the history of technology. STS also received funding from the Mellon Foundation for graduate training in the history and social study of the life sciences.

Administrative Changes, Retirements

The Center for Statistics has been transferred from the School of Humanities and Social Science to the Office of the Vice President for Research. It is now under the administrative control of the Center for Operations Research.

This year has seen a number of retirements and administrative changes within the School. The following faculty members will retire as of June 30, 1990: Professor William Griffith (Ford International Professor of Political Science) of the Political Science Department, Professor Carl Kaysen (Skinner Professor of Political Economy) and Professor Leo Marx (Kenan Professor of American Cultural History) of the Science, Technology, and Society Program, and Professor Robert MacMaster of the History Faculty. We wish them great success in all their future endeavors as emeriti professors of MIT.

The following individuals resigned as Section or Department Head: Professor Jeanne S. Bamberger from Music and Theater Arts; Professor Bruce Mazlish from History; Dean Ann F. Friedlaender as Acting Head of Foreign Languages and Literatures; and Professor Richard Eckaus from Economics. Replacing them in their respective faculties will be Professor Alan Brody of Music and Theater Arts; Professor Peter C. Perdue in History; Professor Isabelle de Courtivron in Foreign Languages and Literatures; and Professor Peter Temin in Economics. In addition, Professor Alvin C. Kibel resigned as Head of Literature last January and was replaced by Professor Peter S. Donaldson. Professor Wayne O'Neil, who has served as Acting Head of Linguistics and Philosophy, has become Head of the department.

We will miss the insights and administrative wisdom of the departing Section and Department Heads and we wish them well as they return to a professional life focused on scholarship and teaching. We are also grateful to the new Section and Department Heads and appreciate their willingness to undertake substantial administrative duties.

Changes in the Dean's office staff include the appointment last September of Ms. Shirley Entzminger-Merritt as Administrative Secretary; the resignation of Ms. Fay Wallstrom, Administrative Secretary, effective July 31, 1990; and the promotion of Dr. David Lundberg, the School's director of development, to Assistant Dean for Development, effective July 1, 1990.

After six years of dedicated service to the School of Humanities and Social Science, Dean Ann F. Friedlaender announced her resignation effective June 30, 1990. She will return to the Economics Department where she holds the Class of 1941 Professorship. Here, we mention only some of her accomplishments during her tenure as Dean. She took the lead in undergraduate curriculum reform at the Institute by sponsoring the restructuring and rejuvenation of the Humanities (now HASS) distribution system, the new HASS Minor program, and Course XXI degrees designated by specific field. She sponsored the highly successful Burchard Scholars Program for undergraduates who excel both in the humanities, arts, and social sciences and in engineering and science and the School's freshman experimental unit, the Integrated Studies Program. She helped to establish MIT's first new doctoral program in fifteen years, the Ph.D. Program in the History and Social Study of Science and Technology, a collaborative effort by the Programs in Science, Technology, and Society and Anthropology/Archaeology and the History Faculty. An active fundraiser, she helped to increase endowment funds and funding for special projects, including HASS curriculum reform. She helped to preserve the position of intellectual leadership enjoyed by the Economics Department and the Linguistics and Philosophy Department in their respective professions and she worked closely with her colleagues in the Political Science Department to help ensure the high reputation of its program as it works to rebuild faculty strength in certain critical areas in the wake of premature deaths, retirements and departures. Above all, she contributed enormously to strengthening the profile of the Humanities faculty by ensuring many excellent appointments at the junior and senior levels and by enhancing the stature and reputation of the Humanities within MIT and in the wider academic world. Under Dean Friedlaender's leadership, the School of Humanities and Social Science has been a much more active contributor than ever before to the overall educational and research mission of the Institute; equally important, the School has played an increasingly vital role in helping to define that mission.

Associate Dean Philip S. Khoury will become Acting Dean of the School of Humanities and Social Science effective July 1, 1990.

PHILIP S. KHOURY

TABLE I
Enrollment in Humanities, Arts, and Social Science Subjects:
1989-90

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	11	135	3	43	4	59	18	237
Economics	18 ⁴⁰	1516	1	37	1	11	20 ⁴²	1564
Foreign Lang & Literature	58 ⁹⁶	1193	8 ¹¹	195	12 ¹⁹	250	78 ¹²⁶	1638
History	20	248	13	232	7 ⁸	279	40 ⁴¹	759
History of Art & Arch	2	21	1	18	3	126	6	165
Interdis	1	2	0	0	0	0	1	2
Linguistics	1	16	1 ²	58	0	0	2 ³	74
Literature	27	343	2	41	22 ³¹	847	51 ⁶⁰	1231
Music	17 ²²	384	1	7	9 ²²	422	27 ⁴⁵	813
Philosophy	17	275	1	32	7	380	25	687
Political Science	22	281	3	65	8	392	33	738
Psychology	9 ¹⁰	496	0	0	1	392	10 ¹¹	888
STS	17	130	5	78	4	111	26	319
Theater Arts	9	85	0	0	4	68	13	153
Urban Studies	4	63	3	68	2	82	9	213
Visual Arts	8 ¹²	139	0	0	0	0	8 ¹²	139
Writing	26 ⁴¹	580	6 ¹⁴	127	4 ⁷	167	36 ⁶²	874
TOTALS	267 ³⁵²	5907	48 ⁶⁰	1001	88 ¹²¹	3586	403 ⁵³³	10494

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.

TABLE II
CONCENTRATIONS IN ALL FIELDS OF HUMANITIES,
ARTS, AND SOCIAL SCIENCES*
JUNE 1990

Fields of Concentration	Class of 1993	Class of 1992	Class of 1991	Class of 1990	Totals in Fields
American Studies	(0) 0	(3) 0	(5) 2	(5) 5	(13) 7
Ancient & Medieval	(0) 0	(4) 0	(3) 0	(7) 7	(14) 7
Anthropology/Archaeology	(0) 0	(8) 0	(5) 1	(13) 9	(26) 10
Economics	(2) 0	(95) 7	(110) 44	(201) 189	(408) 240
Ethnic Studies	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0
Film & Media Studies	(0) 0	(6) 0	(0) 0	(5) 4	(11) 4
Foreign Languages**	(4) 0	(75) 14	(97) 43	(176) 157	(352) 214
History	(1) 0	(18) 2	(30) 11	(67) 63	(116) 76
History of Art	(0) 0	(5) 1	(5) 1	(9) 9	(19) 11
Labor in Industrial Society	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0
Latin American Studies	(0) 0	(2) 0	(0) 0	(0) 0	(2) 0
Linguistics	(0) 0	(3) 0	(1) 0	(7) 4	(11) 4
Literature	(4) 0	(19) 1	(43) 19	(88) 86	(154) 106
Music	(0) 0	(46) 0	(66) 16	(92) 81	(204) 97
Philosophy	(0) 0	(19) 2	(29) 8	(49) 49	(97) 59
Political Science	(1) 0	(16) 2	(35) 17	(65) 62	(117) 81
Psychology	(0) 0	(35) 3	(59) 24	(121) 121	(215) 148
Russian Studies	(0) 0	(1) 0	(1) 0	(7) 7	(9) 7
Science, Technology, & Society	(0) 0	(4) 0	(5) 0	(9) 8	(18) 8
Theater Arts	(0) 0	(5) 0	(5) 4	(5) 5	(15) 9
Urban Studies	(0) 0	(2) 1	(2) 0	(9) 7	(13) 8
Visual Arts & Design	(0) 0	(3) 0	(8) 0	(23) 19	(34) 19
Women's Studies	(1) 0	(4) 2	(10) 3	(12) 12	(27) 17
Writing	(0) 0	(20) 0	(45) 41	(51) 46	(116) 87
Special Concentrations	(0) 0	(9) 2	(13) 6	(27) 27	(49) 35
TOTALS	(13) 0	(402) 37	(577) 240	(1045) 977	(2040) 1254

* 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:

French	(0) 0	(6) 1	(32) 16	(49) 44	(87) 61
German	(3) 0	(17) 2	(16) 4	(37) 35	(73) 41
Japanese	(0) 0	(10) 1	(8) 2	(23) 19	(41) 22
Russian	(1) 0	(10) 3	(12) 6	(11) 11	(34) 20
Spanish	(0) 0	(20) 6	(17) 9	(40) 35	(77) 50
Other Languages	(0) 0	(9) 1	(11) 5	(6) 5	(26) 11
World Literature	(0) 0	(3) 0	(1) 1	(10) 8	(14) 9

TABLE IIIUndergraduate Majors in the School of Humanities and Social Science*

<u>Year</u>	<u>Economics</u>	<u>Humanities**</u>	<u>Philosophy</u>	<u>Political Science</u>	<u>Total</u>
1976-77		67	31	7	130
1977-78		52	34	7	114
1978-79		48	38	5	121
1979-80		44	37	9	126
1980-81		50	40	11	131
1981-82		51	49	9	141
1982-83		48	37	7	120
1983-84		48	24	3	97
1984-85		52	30	2	99
1985-86		51	52	5	134
1986-87		49	57	7	134
1987-88		76	77	9	202
1988-89		103	52	11	209
1989-90		111	51	13	229

* As registered in the second term of academic year 1976-77 to 1989-90. Data taken from the Registrar's fifth-week report.

** These figures do not include double majors who registered first in a course other than Humanities. (If you include double majors, the figure is 87.)

TABLE IVGraduate Students in the School of Humanities and Social Science*

<u>Year</u>	<u>Economics</u>	<u>Linguistics & Philosophy</u>	<u>Political Science</u>	<u>Total</u>
1976-77		114	46	251
1977-78		123	45	270
1978-79		121	48	265
1979-80		138	63	344
1980-81		126	66	313
1981-82		111	55	308
1982-83		136	51	350
1983-84		113	52	264
1984-85		108	53	282
1985-86		130	59	360
1986-87		105	55	275
1987-88		120	72	349
1988-89		127	67	312
1989-90		132	77	363

* As registered in the second term of academic year 1976-77 to 1989-90 (including special graduate students). Data taken from the Registrar's fifth-week report.

TABLE V
HASS MINOR APPLICATIONS
FOR CLASSES OF 1990, 1991, 1992, AND 1993

FIELD	TOTAL APPLICATIONS
Anthropology/Archaeology	5
Economics	89
French	13
German	9
History	17
Literature	42
Music	45
Philosophy	7
Political Science	27
Psychology	40
Russian	6
Science, Technology, & Society	1
Spanish	11
Theater Arts	6
Urban Studies and Planning	0
Women's Studies	9
Writing	25
TOTAL	352

Humanities, Arts, and Social Sciences Office

The HASS Office continued to provide a vast amount of information to the MIT community. Ruth Spear is the coordinator of the Office and Michele Taylor the part-time Senior Secretary. Most inquiries from faculty and students were in regard to the HASS-Distribution system and the HASS Minor Programs. There was a marked increase in the number of questions about the HASS Concentrations due to the fact that in September the HASS Office took on the responsibility, from the Registrar's Office, of recording the proposing and completing of the Concentration on each student's record. Apart from the HASS Requirement the office provided information to the community about MIT-Harvard Cross-Registration, HASS Transfer credit and general Institute information.

HASS Enrollment Statistics by Field and Subject -- Recent Trends

There was an increase of 415 in the number of HASS subjects taken in 1989-90 for a total of 10494. The number of autonomous sections also increased in 1989-90 by 41 for a total of 533. This is the second year of overall increase in both enrollments and sections offered. Enrollments in HASS Elective subjects dropped somewhat from last year (by 108) for a total of 5907 even though there was an increase of 14 in the number of autonomous sections offered for a total of 352. HUM-Distribution enrollments also dropped slightly (by 23 to 1001), again, even though there was an increase (by 12) in sections offered to 60. Predictably, HASS-Distribution enrollments increased greatly (by 546) for a total of 3586 with a growth (by 15) in the number of sections offered for a total of 121. Some statistics worth commenting on are: three year consecutive growth in overall enrollments in Psychology (from 719 in 1986-87 to 888 in 1989-90) and Writing (from 625 in 1986-87 to 874 in 1989-90); both Science, Technology, and Society (STS) and Theater Arts doubled the number of autonomous sections offered (26 and 13 sections respectively) with a corresponding increase in enrollments (319 for STS and 153 for Theater Arts).

HASS Concentrations: Patterns of Popularity

Economics topped the charts again this year as the most popular field of Concentration followed by Foreign Languages and Literatures, Psychology, and Music. This is the first time that Psychology surpassed Music although they have been very close since 1987. There are 408 proposed concentrators in Economics, 352 in Foreign Languages and Literatures, 215 in Psychology, and 204 in Music. There were 206 more proposals this year than last, with the greatest increase in the number of sophomores filing the form. This is perhaps in response to a notification sent to all sophomores reminding them they should file the proposal form by the end of the sophomore year.

HASS Minor Programs

In its second year the total number of students involved in HASS Minor Programs increased by 163 to 352. Two fields were added in 1989-90 for a total of 17, and two more were approved for 1990-91. Of the 352 students who applied for a Minor Program 3 were in the class of 1993, 68 in the class of 1992, 184 in the class of 1991, and 97 in the class of 1990. The same four fields as last year are still the most popular, the only change being Economics replacing Music at the top: Economics (89), Music (45), Literature (42), and Psychology (40).

Harvard Cross-Registration

There was a slight increase from last year in the number of students taking subjects at Harvard: 189 students taking 204 subjects as compared to 182 students taking 183

subjects in 1988-89. Chinese, Korean, Italian and Arabic are still the most popular subjects taken by MIT students.

COURSE XXI

Changes in the Designation of Course XXI Major

In order to ensure uniformity within the majors designated through Course XXI and to recognize the increasing importance of the Humanities within MIT, the Faculty last year approved a change in the designation of the Course XXI major from the generic designation "Humanities" to the following designations: Anthropology/Archaeology; Foreign Languages and Literatures; History; Literature; Music; Science, Technology and Society; and Writing. This first year yielded one major who met the requirements to graduate in Foreign Languages and Literatures (French), two majors with a degree in History, and two majors with a degree in Literature, with an additional 20 currently registered to pursue such degrees within the various programs.

Course XXI Degrees Granted

Three students received their S.B. in February 1989 (1 in XXI-E and 2 in XXI-S); 32 students received the S.B. in June 1990 (15 in XXI -- 5 in their respective areas, 10 in "Humanities", 5 in XXI-E, and 12 in XXI-S) for a total of 35 for the academic year.

Course XXI Enrollment

The May 1990 combined enrollment in XXI (both under the generic "Humanities" designation and in the individual fields), XXI-E, and XXI-S was 87 (37 of whom were double majors). The distribution of these students into the available humanistic fields remained steady, with Literature still dominant, followed closely by Music and Writing.

Course XXI Honors and Awards

Among the more notable distinctions and honors achieved by Course XXI students this year were:

Phi Beta Kappa: Timothy Hsu '90 and Dipanwita Misra '90

Jon A. Bucsela Prize in Mathematics: Timothy Hsu '90

Luis De Florez Award: Elisabeth Stock '90

William Eugene Edgerton Award: Charles Pokorny '91

Writing Prizes: Eric Colburn '92, Alan Grove '90, Jill Halpern '90, Elisabeth Stock '90, Victor Tulli '91

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 junior appointments were made this year, a senior faculty appointment was made in the area of econometrics. The Department also continued to be unusually successful in recruiting graduate students in competition with other leading departments.

FACULTY PERSONNEL

Whitney Newey, who is now in the Department of Economics at Princeton University, accepted the Department's offer of a professorship. Newey is one of the leading theoretical econometricians.

Associate Professor Robert Gibbons will be promoted effective July 1, 1990 from the rank of Assistant Professor. Assistant Professor Philippe Aghion resigned from the Department to accept a position at Ecole Normale Supérieure in Paris, France.

Four senior faculty members, Professors Henry Farber, Stanley Fischer, Daniel McFadden and Richard Schmalensee were on leave during the entire year. Professor Farber spent the year at the Center for Advanced Study in the Behavioral Sciences. Professor Fischer continued on leave as Vice President for Development Economics and Chief Economist at the World Bank. Professor McFadden visited the University of California at Berkeley in the fall term and the California Institute of Technology in the spring term. Professor Schmalensee took leave to serve as a member of the President's Council of Economic Advisers. Professor Michael Piore was on leave during the spring term at the School of Law of Stanford University.

There were three visiting faculty during the year: Professor Ben Bernanke of Princeton University, Professor Douglas Gale of the University of Pittsburgh and Professor Howard Rosenthal of Carnegie-Mellon University. Professor Rosenthal, a political scientist whose visit was supported by the Sloan Foundation, gave a set of special courses covering aspects and approaches of political science of particular relevance to economics.

Robin Wells, who received her Ph.D. from the Department of Economics of the University of California at Berkeley and specializes in international finance, has been a postdoctoral fellow during the year.

The Department maintains its concern with increasing the representation of women and minorities in the economics profession. Almost half of the entering class of graduate students this year were women. In addition, this year the Department sponsored a black woman who had just received her Ph.D. as a post-doctoral fellow and hosted and helped to fund a black male professional as a Visiting Scholar for a semester.

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.

The total number of enrolled graduate students increased by slightly more than six percent this year, partly as a result of a somewhat larger than anticipated class of first year graduate students, partly because of a slight increase in time for completion of the Ph.D.

Undergraduate enrollments continued to climb rapidly, although at a slightly reduced pace from the previous year. There were 111 undergraduate majors in Economics by the end of the year, which is an 18 percent increase over the previous year and a 46 percent increase over 1988-1989. The total enrollment in all undergraduate subjects in Economics this year was 13 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: "The Informativeness of Prices: Search with Learning and Price Uncertainty," (Assistant Professor Roland Benabou with Robert Gertner); Lectures on Macroeconomics, (Professors Olivier Blanchard and Fischer); "The Beveridge Curve," (Professors Peter Diamond and Olivier Blanchard); "The Macroeconomics of Populism," (Professor Rudiger Dornbusch with Sebastian Edwards); "A General Equilibrium Analysis of the Effects of Carbon Emission Restrictions on Economic Growth in a Developing Country," (Professor Richard Eckaus with Charles Blitzer, Supriya Lahiri and Alex Meeraus); "Janis Joplin's Yearbook and the Theory of Damages," (Professor Franklin Fisher with Roger Craig); "Moral Hazard and Regulation in Agency," (Professors Drew Fudenberg and Jean Tirole); "Optimal Incentive Contracts in the Presence of Career Concerns: Theory and Evidence," (Assistant Professor Gibbons with Kenneth J. Murphy); "Reporting Delays and the Incidence of AIDS," (Associate Professor Jeffrey Harris); "Vertical Integration and Market Foreclosure," (Professor Oliver Hart and Professor Tirole); "Flexible Parametric Estimations of Duration and Competing Risk Models," (Professor Jerry Hausman); "The Independent Power Industry and Competitive Procurement of New Generating Capacity," (Professor Paul Joskow); The Age of Diminished Expectations, (Professor Paul Krugman); "The Effects of International Competition on Collective Bargaining," (Assistant Professor Thomas Lemieux); "Work, Labor, Action: Work Experience in a System of Flexible Production," (Professor Piore); "Speculative Dynamics and the Role of Feedback Traders," (Professor James Poterba); "Permanent and Transitory Movements in Labor Income: An Explanation for Excess Smoothness in Consumption," (Assistant Professor Danny Quah); The Maze of Urban Housing Markets: Theory, Evidence and Policy, (Professor Jerry Rothenberg with George Galster, Robert Butler and Joel Pitkin); "Price Discrimination and Retail Configuration," (Assistant Professor Andrea Shepard); "How Economic Ideas Turn to Mush," (Professor Robert Solow); "The State and Industrial Strategy" (Professor Lance Taylor); "Socialism and Wages in the U.S. and Germany," (Professor Peter Temin); "Forecasting the Future Demand and Supply of Industrial Real Estate," (Associate Professor William Wheaton); "A Test for Function Form Against Nonparametric Alternatives," (Assistant Professor Jeffrey Wooldridge).

FACULTY HONORS

Professor Blanchard was elected to the American Academy of Arts and Sciences. Professor Diamond was elected as the First Vice President of the Econometric Society. Professor Dornbusch was made an honorary professor at the Universidad del Pacifico. Professor Fudenberg was the recipient of a Guggenheim Fellowship. Assistant Professor Gibbons was appointed the Pentti J. Kouri Career Development Professor, was named as an Alfred P. Sloan Research Fellow and received an NBER Olin Fellowship. Professor Solow received honorary degrees from Boston College, Colgate University, Dartmouth College and the University of Helsinki. Professor Tirole received an honorary degree from Université Libre de Bruxelles.

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 Blanchard lectured widely in this country and abroad at universities, the OECD, the Federal Reserve System and in Poland. Professor Diamond was a member of the Panel of Technical Experts of the Advisory Council on Social Insurance. Professor Dornbusch also lectured widely in the U.S. and abroad and in the IMF and World Bank. Professor Fisher, in addition to his public lectures, is a member of the Board of Trustees of the Combined Jewish Philanthropies. Professor Hausman was a member of the Governor's Revenue Advisory Commission for Massachusetts. Professor Joskow testified before Congress and a number of regulatory agencies. Professor Krugman served on the Group of Thirty. Professor Piore is a member of the National Council on Employment Policy. Professor Rothenberg served on the MacArthur Foundation Committee on Arms Control. Professor Solow was a member of the Carnegie Commission Committee on Science, Technology and Government.

Departmental Gifts and Research Grants

The Department continues to receive substantial financial support from its alumni and friends. Pentti J.K. Kouri, Ph.D. 1975, endowed a career development professorship. Substantial grants for graduate student support were also received from Helmut Weynar and Howard Head.

The AT&T corporation donated 12 computers to upgrade the graduate student microcomputer center in the Department.

Department of Humanities

Anthropology/ Archaeology Program

In 1989-90, the Anthropology/Archaeology Program continued developing several new initiatives in teaching and research which involve collaboration with other departments/entities in the Institute. Associate Professor Arthur Steinberg completed his second year directing the Integrated Studies Program. Professor Jean Jackson taught a graduate proseminar and worked with colleagues in the History Section and the Program in Science, Technology and Society to further consolidate the second year of the PhD program in the History and Social Study of Science and Technology. The A/A Program's lecture series on "Peoples and States: Ethnic Identity and Struggle," co-sponsored by the Center for International Studies (with additional funding from the Provost's Office), hosted 11 distinguished speakers, all sessions very well attended. A second series of equally stimulating seminars is being planned for '90-'91.

Associate Professor James Howe was promoted, effective July 1, '90, to full professor while on leave at the Institute for Social Anthropology at Oxford University. Assistant Professor Dorothy Hosler and Assistant Professor Lisa Rofel joined the Program fresh from post-doctoral fellowships; Assistant Professor Hosler holds a joint appointment with the Center for Materials Research in Archaeology and Ethnology, and Assistant Professor Rofel holds a joint appointment in STS. Both have developed new undergraduate subjects.

Five Program faculty have books in progress. Professor Martin Diskin published two articles and has one in press; he also published five articles in newspapers and magazines and written two extensive research reports. Associate Professor Howe has an article in press, and Professor Jackson published three articles and has four in press. Assistant Professor Rofel published one article and has another in press, and Assistant Professor Hosler has two articles in press and co-authored Ax-monies and their Relatives (Dumbarton Oaks) with Professor Heather Lechtman. Associate Professor Steinberg co-authored pieces in Comparative Studies in Society and History and in Studies in Conservation. Professors Jackson and Lechtman and Assistant Professors Rofel and Hosler all received grants for their research activities. Program faculty gave talks in such disparate locales as Ft. Benning, Bennington, San Francisco, Oxford, Seattle, Washington, D.C., New Orleans, Rio de Janeiro, Atlanta, and Bogotá. Professor Lechtman is spending the summer doing archaeological field research in Peru and Bolivia.

Associate Professor Steinberg is also involved in implementing ISP-inspired curricula in the public schools of Cambridge and Quincy, partly funded by an anonymous gift of \$69,000. An IAP activity Professor Jackson was involved with won the Campus Outreach Opportunity League national award; Professor Diskin and Assistant Professor Rofel also participated in IAP. All Program faculty have been involved in designing and teaching new HASS-D subjects, and two participate on HASS review committees. We have four times as many minors as last year, and concentrators have increased by two-fifths.

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.

JEAN JACKSON

Foreign Languages and Literatures Section

Members of The Foreign Languages and Literatures Section (FLL) have continued to demonstrate energetic scholarly and professional involvement, commitment to excellence in teaching, and intense collaboration in the HASS reforms underway at the Institute. The Section has received substantial research support from the Consortium for Language Teaching and Learning; it has also increased its participation in the Athena Language Project, which has generated national recognition.

Two works have been published by faculty and lecturers within FLL. The second edition of *Reden, Mitreden, Dazwischenreden* (Heinle & Heinle), a German language text by Professor Claire Kramsch and Lecturer Ellen Crocker, was published in February. Professor Catherine V. Chvany co-authored (with Slava Paperno and Richard Leed) *Graduated Word-Nest Generator for Intermediate Russian* (Exceller software, Inc.), an educational software package and user's guide. Professor Chvany also authored the *Teacher's Manual* (Consortium for Foreign Language Teaching & Learning) for this same software. Other members of the faculty are pursuing on-going research in the following areas: Linguistics, Second and Foreign Language Acquisition (Professor James Harris, Associate Professor Suzanne Flynn and Assistant Professor Michio Tsutsui); Foreign Literary Studies (Professor Robert Jones, Associate Professors Isabelle de Courtivron, Elizabeth Garrels, and Margery Resnick); and Film and Media Studies (Professor Edward B. Turk).

FLL hosted several guest lecturers including author Elisabeth Higonnet-Dugua, who lectured on French poet Anna de Noailles, and German poet Uwe Timm (co-sponsored by the Goethe Institute Boston and the American Association of Teachers of German), who read from his new book *The Snake Tree*. Other events included the showing of several post-glasnost Soviet films, a German Lied workshop and a very successful Work/Study in France workshop.

Two faculty in FLL were recognized for their recent research efforts. Professor Turk was the recipient of a prestigious prize awarded by the Theater Library Association for his book *Child of Paradise: Marcel Carné and the Golden Age of French Cinema* (Harvard University Press, 1989). Three awards went to Senior Lecturer Gilberte Furstenberg for the outstanding success of her interactive fiction videodisc, A la recontre de Philippe. The awards are: a gold medal from CINDY (Cinema and Industry), Los Angeles, October 1989; the Mark of Excellence by IICS (International Interactive Communications Society), Washington, DC, November 1989 and the Merit Award from the 1990 Nebraska Videodisc Competition, Nebraska, May 1990.

Construction for the new Language Learning & Resource Center began in Building 20. The Center will have 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. Completion is expected in August of 1990 and the new classrooms will be utilized starting in September.

The total enrollments (1958) are up 12 percent from the 1988-89 figure of 1751. The number of majors (nine) has remained constant while concentrators (total: 216) has increased slightly and minors (37), as expected, has increased dramatically. This year, Spanish has the largest enrollments (376), followed by French (363), World Literature in Translation (304), German (278), Japanese (249), Russian (218), and English as a Second Language (168). FLL subjects continue to receive some of the highest ratings in the Student Course Evaluation Guide.

Personnel changes this year include the retirement of Professor Kramsch and the departure of Assistant Professor Tsutsui, who has accepted a position as Associate Professor of Japanese at the University of Washington. Administrative Assistant Karen Booth left in November and was replaced by Zachary Knight. Associate Professor Turk will be promoted to rank of Full Professor effective July 1990. Dean Ann F. Friedlaender is resigning as Acting Head of FLL and Associate Professor De Courtivron will assume the position of Head as of July 1. FLL has assumed a leadership role in the hiring of women with 78 percent of its faculty being women and continues to seek out minority candidates for every job search.

ANN F. FRIEDLAENDER

History Section

APPOINTMENTS AND SEARCHES

The History Faculty is passing through a period of dramatic transformation with the retirement of three of its senior faculty and the need to replace two positions in American history. A nationwide search to replace the retiring Professor Robert E. MacMaster in Russian history led to a successful offer to Elizabeth Wood, from the University of Michigan, who specializes in the experience of Russian women during the Bolshevik Revolution. Two rank-open searches for American political and social historians yielded an offer of full Professor to Alexander Keyssar, a labor historian at Duke University well known for his prize-winning study of unemployment in Massachusetts in the nineteenth century. The search for a junior American historian will be reopened next year. Support from the Luce Foundation for an interdisciplinary position in international peace and security studies (The Henry R. Luce Chair in International Cooperation and Global Stability) allowed us to entice away from the West Coast the leading historian of modern Japan, Professor John W. Dower, nationally known for his prize-winning study (War Without Mercy: Race and Power in the Pacific War). His appointment in the History Faculty will commence in July 1991. We are greatly excited by this opportunity to contribute to the growing strength of Japanese studies at MIT.

The History Faculty has constantly attempted to promote the Affirmative Action objectives of diversity and multi-cultural awareness, both by creating a curriculum which covers the globe in its courses on European, American, and non-Western history and by increasing the diversity of the faculty. This year's new appointments will substantially modify the traditional white male domination of our faculty. Four of our six job offers this year were to women. Ongoing efforts to create a minority appointment brought a lecture invitation to Professor Colin Palmer, now Chair of the History department at the University of North Carolina-Chapel Hill, known for his work on slavery in Latin America. After considering other candidates next year, we will try to make a visiting appointment to help fill our needs in this field.

Associate Professor Philip S. Khoury will be promoted to Full Professor effective July 1, 1990. He served as Associate Dean of the School of Humanities and Social Science for the past three years and will become Acting Dean on July 1, 1990. Associate Professor Peter C. Perdue will succeed Professor Bruce Mazlish as Head on July 1, 1990.

PUBLICATIONS AND RESEARCH

Current members of the department active in publishing and research were: Associate Professor David B. Ralston, who published Importing the European Army (University of Chicago Press) this year; Associate Professor Khoury, who co-edited Tribes and State Formation in the Middle East (University of California Press); Professor Mazlish, who published A New Science: The Breakdown of Connections and the Birth of Sociology (Oxford University Press) and completed The Leader, the Led, and the Psyche: Essays in Psychohistory; and Professor Robert Fogelson, who published America's Armories: Architecture, Society, and Public Order (Harvard University Press). Associate Professor William B. Watson edited the dispatches of Ernest Hemingway from the Spanish Civil War; Associate Professor Perdue completed a chapter on Chinese grain markets forthcoming in a volume on Economics and Chinese history. Professor Pauline Maier completed articles on the impact of the American Revolution; Professor Harold Reiche published articles on historical astronomy and lectured on "Diplomacy and Technology in the Ancient World" to a meeting he organized at MIT of the Junior Classical League of America.

HONORS AND AWARDS

Recipients of nationally competitive fellowships included Professor Maier, who received a Guggenheim fellowship, and Associate Professor Perdue, who received an American Council of Learned Societies Fellowship in Chinese Studies to supplement his sabbatical leave. Professor Maier also was selected as the next William R. Kenan, Jr. Professor of American Cultural History at MIT. Assistant Professor Douglas Forsyth received a prize from the American Historical Association for best unpublished manuscript in Italian history.

OTHER ACTIVITIES

Professor Mazlish promoted interdisciplinary cooperation by co-directing the History and Literature Workshop and by inaugurating the new Trilateral Workshop for discussion of issues of common interest to historians in the Program in Science, Technology, and Society (STS), History, and the Writing Program. Associate Professor Harriet Ritvo of the Writing program will teach a new course in British history next year. Historians collaborated with STS in the planning discussions of the Dibner Institute for the Study of the History of Science and Technology. The first Dibner Workshop, held at MIT on "Men and Machines", included presentations from Professors Mazlish, Merritt Roe Smith, and Associate Professor Perdue, who also co-directed the Asian Council workshop series on Political Development in Asia. Visiting Assistant Professor Hasan Kayali co-directed a symposium on "Islamic Visual Arts and Cultural Expression", sponsored by the Aga Khan Program. Associate Professor Khoury continued to chair the Emile Bustani Middle East Seminar Series.

Outside the Institute, Associate Professor Ralston and Associate Professor Khoury taught courses at the Harvard Extension School, and Professor Reiche lectured at Suffolk University. Assistant Professor Forsyth co-directed the Italian Studies Group at the Harvard Center for European Studies. Associate Professor Perdue delivered lectures for the China Institute and the Asia Society on environmental problems of contemporary China. Associate Professor Khoury was elected to the Board of Directors of the Middle East Studies Association of North America, and he delivered papers at the University of Erlangen, Germany, and at Boston University. He co-chairs the Middle East Security Project of the American Academy of Arts and Sciences. Professor Mazlish and Associate Professor Khoury continue to serve on the editorial boards of several professional journals.

Within the Institute, historians served on Committees such as the Faculty Policy Committee, Faculty Library Committee, HASS-D Overview Committee, Committee on Discipline, Committee on the Undergraduate Program, Committee on Curricula and IAP Policy Committee. In graduate education, Professor Mazlish taught the Historical Methods seminar for graduate students in the Ph.D. program in the History and Social Study of Science and Technology. Assistant Professor Forsyth served as advisor for a doctoral student in Political Science.

In undergraduate education, 6 of the 13 students in the new History Minor Program took the Seminar on Historical Methods with Associate Professor Arthur D. Kaledin. There were 5 majors and 13 minors. Sixty-three students chose to concentrate in history as part of their Humanities, Arts, and Social Sciences (HASS) Requirement. The number of students taking history courses during the academic year totaled 805.

Associate Professor Watson replaced Professor Reiche as Housemaster of Baker House. Visiting Assistant Professor Ronald Edsforth and Associate Professors Kaledin and Perdue supervised undergraduate theses on topics ranging from the Vietnam War in film to the Japanese cloning of Interleukin-2. Professor Richard Douglas and Assistant Professor Forsyth have completed the syllabus for the new two-term course "The Last Hundred Years: Topics in World History" and will pioneer it in Fall 1990. This course, a collaborative venture of the whole History Faculty, aims to overcome the traditional national

specialities of historians by stressing the linkages between events and processes around the globe during the twentieth century, and it will include examination of the effects on world-historical change of the interaction between humans and the natural environment.

PETER C. PERDUE

Literature Section

The Literature Faculty at M.I.T. has become an intensely and diversely productive group whose contributions to film and media study and various forms of cultural study as well as to literary scholarship are widely respected. During the current year, a number of long-term projects came to fruition and a number of faculty members achieved new levels of distinction with the publication of major contributions to their fields. Two of Professor David Halperin's books have appeared this year: One Hundred Years of Homosexuality and other Essays on Greek Love (Routledge) and Before Sexuality: The Construction of Erotic Experience in the Ancient Greek World, co-edited with John Winkler and Froma Zeitlin (Princeton University Press); Professor Irene Tayler published Holy Ghosts: The Male Muses of Emily and Charlotte Bronte (Columbia University Press); Professor Peter S. Donaldson published Shakespearean Films / Shakespearean Directors in Unwin Hyman's Media and Popular Culture Series, edited by Professor David Thorburn. Associate Professor John Hildebidle's The Errand of Keeping Alive: Five Irish Writers was published by Harvard University Press; and Professor Stephen Tapscott published a volume of poetry entitled Another Body with Cleveland State University Press. During the year, Professor A.R. Gurney's play Love Letters, with its innovative use of rotating casts of two performers, continued its notable international success.

Members of the faculty currently have a number of books under contract: Professor Thorburn: "Story Machine: Prime Time Television in the Network Era" (Oxford); Professor Cynthia Wolff: "Edith Wharton, Vol. II" (edition and notes: The Library of America), "Four Works by American Women Writers" (edition: Penguin), and "The Woman Who Made War: Harriet Beecher Stowe" (Knopf); Assistant Professor Henry Jenkins: "Textual Poachers: Television Fans and Participatory Culture" (Routledge); Professor Halperin: "The Metaphysics of Desire: Plato and the Origins of Erotic Theory in the West" (Yale University Press). Associate Professor Theoharis Theoharis has been named editor of "Canons in Context," a series of critical books to be published by Harvard University Press. Articles by faculty members appeared in various journals, including Massachusetts Review, Eighteenth Century Life, Technology Review, Journal of English and Germanic Philology, Library of America, History and Theory, Proceedings of the Boston Area Colloquium in Ancient Philosophy, Arethusa; as a chapter in The Art of Television (Mazzeo and Henderson, eds.), and poems and stories have appeared in Worcester Review, Yankee, The Nation, Tar River Poetry, Agni, and Other Arts.

This year, Professor Wolff gave a series of lectures at Japanese universities as a guest of the Emily Dickinson Society of Japan. Members of the faculty gave papers or addresses at meetings of MLA, the Michigan Feminist Conference, Northeast Modern Language Association, American Literature Conference, American Psychoanalytic Association, New England Historical Association, Society for Cinema Studies, the Cultural Studies Conference (University of Illinois, Champaign-Urbana), David Nichol Smith Seminar (Melbourne, Australia), American Society for Eighteenth Century Studies, Berkshire Conference on the History of Women, International Congress on the History of Science (Munich, Germany) and spoke at many colleges and universities including Hebrew University, Bir Zeit University, City University of New York, Bowdoin, Harvard, University of Michigan, University of California, Brandeis, University of Iowa, University of Montana, University of Rochester, and Columbia University.

Professor Tapscott was appointed Fellow of the Karolyi Institute, Vence, France, for the summer of 1990, and was awarded a Grant for Poetry from the Massachusetts Arts Council. Professor Alvin Kibel has been Visiting Scholar at Pembroke College, Cambridge University.

Professor Jenkins, who holds a PhD in Film from Wisconsin, joined the faculty as Assistant Professor this year. Assistant Professor Rita Goldberg will be promoted to Associate Professor beginning July 1, 1990. As the result of a search process extending over several years, Louis Galdieri (University of California, Berkeley) and Mary Fuller (The Johns Hopkins University) will be joining the faculty as Assistant Professors in the Fall of 1990. Dr. Kai Hong, who holds a PhD in Philosophy from MIT and is a distinguished playwright and art historian in Korea will be joining us as Visiting Professor of Literature next year, and will concurrently hold the first Fellowship of the Ye-Eum Cultural Foundation.

During the past year, 1285 students enrolled in Literature subjects, 26 were registered as Literature majors, 17 as minors, and 89 elected to concentrate in Literature for the HASS requirement. The Literature Faculty continues to participate actively in the curricular reforms of the School: for next year, several innovative and collaborative HASS-D subjects will be offered for the first time, including The End of Nature taught Professor Kibel and Professor James Paradis (Writing) and Forms of Western Narrative, taught by Professor Thorburn. The Film and Media Program at MIT, which includes subjects offered by Professors Thorburn, Donaldson, and Jenkins, was the recipient of this year's Irwin Sizer Award for Most Significant Improvement to MIT Undergraduate Education. Though there is no graduate program in Literature, members of the faculty have begun to plan programs that may be expected to provide opportunities for advanced teaching. Professor Ruth Perry, assisted by a grant from the Ford Foundation, is planning an area-wide Graduate Consortium in Women's Studies; Professor Donaldson co-directed a four-month Study Seminar for College and University Teachers in Film Style and Film Technology for Shakespeareans for the Shakespeare Association of America, and Professors Halperin and Thorburn have been active in plans for the Cultural Studies Project at the Institute. An international conference on Epidemics is planned for October, 1990 as the inaugural event of the Project, and Professor Thorburn has been appointed Director of this new venture, which will provide a focus for a number of interdisciplinary interests and activities in the School.

The current objectives of the Literature Faculty include maintaining and extending our participation in film and media, cultural studies and gender studies while maintaining a central commitment to literature; fine-tuning the curriculum to serve the needs of majors, concentrators, and students who elect the new minor. In regard to Affirmative Action, the Literature Faculty is planning to renew its efforts to recruit minority faculty and to strengthen our offerings in African-American and ethnic literatures. (This year we made an offer to a distinguished senior African-American scholar which was declined.)

Professor Kibel resigned as Head of the Literature Faculty in January, 1990 to return to full time teaching and research, and was succeeded by Professor Donaldson. Professor Kibel served as head for 14 of the last 16 years. Under his leadership the Literature Faculty has made steady progress toward its goals of professional excellence and scholarly distinction, and, as we look forward to new tasks and new challenges, his colleagues are grateful for his generous contributions to the collegiality and intellectual vitality of our enterprise.

PETER S. DONALDSON

Music and Theater Arts Section

Most notable this year in the Music and Theater Arts Section was the rapid expansion of activities in theater and dance. Along with a steady growth in the music program, the Section is approaching its goal of building a strong, synergistic structure in which music, theater, and dance are contributing equally to the academic and concert life of the Institute.

The theater program successfully put in place a full and coherent curriculum this year, enabling five students to graduate with minors in this area. Response to new course offerings, particularly at the introductory level, was enthusiastic. The year was also marked by a proliferation of excellent student-written one-act plays, three of which were produced by the Playwrights Workshop and three by the Dramashop. Other student productions included G.B. Shaw's Arms and the Man, and Shakespeare's King Lear, along with a number of workshop productions. Members of the Pilgrim Theater, our first guest artists, participated in teaching acting courses, and also developed and performed Leonardo, a multi-media production which included students and faculty as well as members of the Pilgrim Theater. The dance program, directed by Senior Lecturer Beth Soll, also enjoyed an increase in student involvement. Ms Soll's new course, Introduction to Modern Dance, which integrates theory and performance, was approved for HASS distribution credit.

This year, 1115 students enrolled in credit-bearing music courses, with an additional 385 participating in co-curricular performance activities directed by the Section. Among graduating seniors there were 81 music concentrators, 16 music minors, and 5 music majors. The faculty continues its efforts to integrate the three foci of the music program--performance, theory/composition, and music history. To this end, students enrolling in the introductory theory and history courses now attend weekly Labs where they have opportunities to participate actively in making music, while gifted student performers are enrolling in increasing numbers in theory and history courses. There was a continuing strong interest in our theory sequence. While 110 students enrolled in the HASS-D course, 21.641 Harmony and Counterpoint I, this number was limited only by lack of classroom space and teaching faculty. The continuity of interest in the theory program was reflected in several concerts of outstanding original compositions by students in Professor John Harbison's advanced composition class.

With the rapid expansion of classroom enrollments, new courses, and performance activities, space continues to be a problem, heightened this year by lack of facilities for the expanding activities in theater arts and dance. While the new Office of the Arts under the leadership of Associate Provost Ellen Harris has been of assistance in helping to remediate this situation, office space, studio space, as well as rehearsal and practice rooms still remain in short supply. Dean Friedlaender has, however, approved the upgrading of the Computer Music Lab in Building 20 and Apple Computer has donated ten Macintosh computers to be used in this new facility.

Killian Hall, which continues to make a major contribution to our music and theater facilities, was the site of numerous chamber concerts this year by MIT faculty and students as well as visiting artists. These included 14 recitals by students selected by competitive audition to participate in 21.658/59 Advanced Music Performance, and also the new, noontime Bach Cantata Series directed by members of the music faculty which consistently performed to standing room only audiences.

Other concerts sponsored by the Section continue to flourish, numbering 107 in all. The Guest Artist series was dominated by four well-attended string quartet concerts performed respectively by the American, Chilingirian, Orion, and Coull String Quartets. Avery Brooks, actor and musician, gave the annual Abramowitz concert this year. MIT music organizations had productive seasons. Of special note were the performances by the MIT Symphony Orchestra under guest conductor Richard Cornell in a stellar performance of Gershwin's Rhapsody in Blue with graduating senior Benny Weintraub as piano soloist, and a performance by the Concert Choir of the Brahms German Requiem directed by Senior Lecturer John Oliver.

Four students received awards for their outstanding work in music. Daniel Schmidt and Charles Pokorny shared the Edgerton Award for their compositions, and pianists, Jee Hoon Yap and Jee Lian Yap, received the Wiesner and Sudler Awards, respectively, for contributions to the Section and to the community in their many solo and chamber music concerts.

Faculty and staff continue to be professionally active. Professor Jeanne Bamberger was a fellow at the Institute for the Humanities at the University of Michigan in January and her work in music cognition resulted in a number of new publications including her book, The Mind Behind the Musical Ear, which will be published by Harvard University Press. Professor Alan Brody's play, "Five Scenes From Life," was produced by the Missouri Repertory Theater, and there was a staged reading of another play, "Clara At One in the Morning," at the Westbeth Theater in New York City. Assistant Professor Peter Child was a participating composer at the USA-USSR Young Composers Symposium in the Soviet Union where three of his compositions were performed, and the world premiere of his String Quartet #2 was performed by the Lydian Quartet at Brandeis University. Professor David Epstein lectured and conducted in Germany and Mexico this year and his paper, "Musical Structure and Neurophysiological Implications" was published in the proceedings from the Herbert von Karajan Symposium of 1988. Professor Marcus Thompson, who was on sabbatical leave this year, gave solo and chamber music concerts across the country as well as in Yugoslavia and Alaska. He also performed in several new recordings including the Shostakovich Piano Quintet and the Brahms Clarinet Quintet.

Professor Harbison, who received the prestigious MacArthur Award this year, had performances of his most recently completed works including "Concerto for Viola" performed by the New Jersey Symphony and "Concerto for Double Bass Choir" performed by the Los Angeles Philharmonic under the direction of Andre Previn. Professor Harbison will be on leave next year to accept his appointment as Creative Chair for the St. Paul Chamber Orchestra. Our newest colleague, Associate Provost Harris, in addition to her administrative responsibilities, was soloist with the MIT Symphony conducted by Professor Epstein in the Berlioz "Nuits d'Ete." Continuing her scholarly work in musicology, Professor Harris's publications this year included "Voices" in The New Grove Handbooks for Music, as well as reviews in the Journal of Musicological Research and the American Recorder.

Assistant Professor Martin Marks gave a number of lectures on film music around the country and a book based on his recently completed PhD dissertation has been accepted for publication by Oxford University Press. Senior Lecturer Edward Cohen's Clarinet Quintet was performed by Laura Flax and the Atlantic String Quartet; Senior Lecturer Oliver was guest conductor at the Tokyo Oratorio Society in a performance of Handel's Messiah with the Japan Shinsei Orchestra. Senior Lecturer Beth Soll gave a solo concert in Hungary and, along with the Beth Soll Dancers, gave several performances of two of her choreographed works, A Shaker Dance and Dreams and Illusions.

A new appointment and one promotion were confirmed this year. The appointment of Evan Ziporyn as Assistant Professor of Music has been approved. Dr. Ziporyn, a composer and clarinetist who has also extensively studied and performed Balinese gamelan music, will be an important new addition to our theory faculty. His appointment along with Assistant Professor Peter Child's promotion to Associate Professor will take effect on July 1, 1990.

Jeanne Bamberger

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.

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. At "An Evening of Poetry with John Ashbery," the renowned poet Ashbery read from his recent work. Anne Lauterbach rendered a sensitive and moving poetry reading of recent and past work. The acclaimed naturalist writer David Quammen gave an informative and stimulating talk on "The Song of the Dodo: Visions from a Work in Progress."

Assistant Professor Rosalind Williams published a new book entitled Notes on the Underground: An Essay on Technology, Society, and the Imagination (Cambridge: MIT Press, 1989). She will be promoted to the rank of Associate Professor with tenure, effective July 1, 1990. Associate Professor James Paradis will be appointed to the rank of Professor, effective July 1, 1990. Associate Professor Harriet Ritvo spent the spring semester at the National Humanities Center in Research Triangle, North Carolina working on her new book on Taxonomy in the nineteenth century. Professor Alan Lightman has completed his book of interviews of leading cosmologists which will be brought out by Harvard University Press in the coming fall. Professor Elzbieta Chodakowska continues her biography of Hannah Arendt. Professor Kenneth Manning was recently selected by the History of Science Society to deliver 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." Part-time lecturer Robin Becker published a collection of her poems, Giacometti's Dog (Pittsburgh: University of Pittsburgh Press, 1990), and Visiting Writer Ruth Whitman translated an edition The Fiddle Rose: Poems 1970-1972, Abraham Sutzkever, (Detroit: Wayne State University Press, 1990).

The novelist David Bradley joined the program last fall term as a Visiting Professor. Assistant Professor Thomas Simmons will be on leave for the coming fall term on an Old Dominion Fellowship.

Department of Linguistics and Philosophy

Research: Linguistics

Linguistic research this year included the following: implications of the principles of economy for the study of the phenomena involving locality of movement, admissible chains, and the Empty Category Principle; question formation and other movement processes in Papago and the evolution of free word order in that language; morphology and its interaction with other grammatical modules; conceptual foundations of cognitive science in relation to the nature and limits of the study of natural language in its syntactic and semantic aspects.

Research: Philosophy

Research in philosophy included the following: conceptual issues in cognitive science; natural kinds; categorical imperatives and Kantian rationalism; Hegel's social philosophy; Cartesian dualism and Cartesian passions; time-asymmetry, rationality, and the nature of meaning; foundations of game theory; foundations and applications of modal semantics; issues in the philosophy of mathematics; justice and the demise of slavery.

Publications

As in the past, the faculty of both sections of the Department published a large number of chapters in books and articles and reviews in professional journals. In addition, Professor Paul Horwich's book, *Truth*, was published by Basil Blackwell, Oxford.

Honors and Awards

Assistant Professor David Brink was invited to be a Resident Fellow at the Center for Advanced Study in the Behavioral Sciences, Stanford, for the academic year 1990-1991. Institute Professor Noam Chomsky was made an Honorary Fellow of the Royal Anthropological Institute of Great Britain and Ireland and an Honorary Member of the *Gesellschaft für Sprachwissenschaft* of West Germany. Associate Professor Joshua Cohen was the recipient of the Institute's first Levitan Award. Ferrari P. Ward Professor Kenneth Hale was elected to the National Academy of Sciences. And Assistant Professor Michael Hardimon was awarded a Ford Foundation Post-doctoral Fellowship for Minorities for the academic year 1990-1991.

In May, the Department held a conference in honor of Laurance S. Rockefeller Professor Thomas Kuhn, in which his impact on current work in the history and philosophy of science was examined. Supported by a grant from the Sloan Foundation, this highly successful event featured papers by many distinguished scholars in these fields, concluding with an address by Professor Kuhn.

Leaves of Absence

Supported by Old Dominion fellowships, Assistant Professors Hardimon and Paul Hoffman were each on leave for one term, Professor Hardimon continuing research for his book on Hegel; Professor Hoffman continuing his research on seventeenth century Western philosophy. While on sabbatical leave and further supported by an NSF grant, Professor Kuhn worked on his book about scientific development and lexical change.

Personnel

With regret, we announce the resignation of Associate Professor Donca Steriade. She will take a position in the UCLA Department of Linguistics, where she has been on leave this year. As Professor Steriade's replacement, we were fortunate in being able to have

with us throughout the year Professor François Dell, Director of Linguistic Research, CNRS, Paris.

We are pleased to report that Associate Professor Cohen, who holds a joint appointment with the Department of Political Science, was promoted to the rank of Professor.

And it is also with pleasure that we announce the appointments of Professor Michael Kenstowicz and Associate Professor Alec Marantz, who will join the linguistics faculty on 1 July 1990. Professor Kenstowicz will work primarily in phonology; Professor Marantz in syntax and morphology.

The Department's major affirmative-action goal, to increase the representation of women on the faculty, was dealt a serious setback with the resignation of Professor Steriade. It thus still remains for us to achieve our goal of having three women faculty members, as opposed to the present two. Unfortunately, no such nearby attainable goal is possible in the case of members of underrepresented minority groups, for their presence in philosophy and, especially, in linguistics is discouragingly small.

Having acted as Head of this department during the present year, I am encouraged to believe that assuming its headship will present no fewer pleasures and -- perhaps -- fewer difficulties.

WAYNE O'NEIL

Department of Political Science

Building new faculty strength continued as a major focus of the Department of Political Science's efforts in 1989-90. For Political Science in all major universities, faculty recruitment and replacement will be preoccupying concerns through the next decade, as a wave of retirements empties senior ranks. The ensuing competition for outstanding younger scholars has already produced salary escalation and demands for increased housing subsidies, more institutional support for research, and reduced teaching loads. The most professionally visible members of our Department are being actively wooed by other institutions, and retaining our own best faculty members has become a serious area of concern. Our planning and recruitment efforts over the past four years in the critical field of International Relations finally bore fruit in 1989-90 with two major appointments. Professor Kenneth A. Oye, currently teaching at Swarthmore College, will join our faculty as Associate Professor with tenure. Professor Oye is a specialist on U.S. foreign policy and on international political economy. He will also become Housemaster at East Campus. Professor Stephen W. Van Evera, known for his work in international security studies, has been appointed Assistant Professor. Increasing the presence of underrepresented minorities on the faculty is a major concern. The faculty regards the underrepresentation of minorities in the Department as a significant source of weakness, both in our ability to present a wide variety of perspectives and in our responsibility to train future citizens and political scientists. We plan to continue (1) special faculty meetings to discuss broadening the base of minority student and faculty recruitment; (2) wide advertisement of our faculty positions and special letters about these positions to minority faculty around the country; and (3) considering visiting appointments of underrepresented minority members with distinguished careers in the professions. A successful example of the latter is Ms. Margaret Burnham, a Black attorney and former Boston Municipal Court judge, whom we appointed as Lecturer in 1989-90 and who will continue in 1990-91.

Four promotions will occur effective July 1, 1990: Assistant Professor Richard M. Valelly will become Associate Professor; Associate Professors Joshua Cohen, Stephen M. Meyer, and Richard J. Samuels will be appointed Full Professors. Professor Charles F. Sabel was named Ford International Professor of Political Science. Associate Professor Charles Stewart III was selected as a Cecil and Ida Green Development Professor. Two visiting scholars were chosen to teach in the Department: Ms. Burnham will continue the subjects she taught in 1989-90 on American constitutional law, and law and public policy. Visiting Associate Professor Hannes Adomeit will teach on German-Soviet relations. After 32 years at MIT, Professor William E. Griffith retired on June 30. We celebrated his wide-ranging research and teaching contributions with a day of research presentations by many of his former students now working on West and East Europe, the Soviet Union, and East-West relations.

The Department's undergraduate and graduate teaching continues to flourish. We now have 54 majors, in contrast to 46 in 1988-89 and 21 in 1984-85. New subjects, for example Professor Willard R. Johnson's HASS-D on African civilizations and Professor Donald L.M. Blackmer's on the evolution of Soviet politics, have been developed. The internship program and the junior seminars for majors are growing rapidly, as are enrollments in HASS-D subjects taught by the Department. Tobie Weiner, the administrative assistant for the undergraduate program, received the James N. Murphy Award for her contributions. Among the successful offerings for undergraduates in 1989-90 were two subjects on Black politics and ideology taught by Visiting Professor James Jennings.

The financing of students in the graduate program is a major preoccupation, for current support levels make it difficult to compete with other top departments for the best students. We are also keenly aware of the strain that inadequate funding puts on our current student body, a point heavily emphasized in the last Visiting Committee Report.

Several new teaching initiatives at the graduate level merit mention. Adjunct Professor Ronald P. Dore and Assistant Professor Richard M. Locke have developed a comparative subject on Italy and Japan. Professor Myron Weiner, Director of the Center for International Studies, created a workshop for graduate student recipients of MacArthur international peace and cooperation grants. The workshop brings together students from the Departments of Political Science, Economics, and Urban Studies and Planning. The Defense and Arms Control Program, headed by Professor Harvey M. Sapolsky, has established six student-faculty working groups.

The scholarship of the faculty remains the Department's strongest asset. A list of articles and monographs would be too long to reproduce here; we note only recent books and those to appear before the end of 1990. Professor Nazli Choucri's "Population and Political Economy in Egypt: Challenges to Security" and "Conflict and Contention: A Century of Growth and Expansion in Japan" (with Robert C. North and Susumu Yamakage) will appear this fall. Adjunct Professor Dore published Japan at Work: Markets, Management and Flexibility (with Jean Bounine-Cabale and Kari Tapiola), and his "Will the Twenty-First Century be the Century of Individualism?" and "Corporatism and Accountability" (edited with Colin Crouch) will appear this fall. Professor Lucian W. Pye brought out a fourth edition of China: An Introduction. Professor Weiner published The Child and the State in India: Child Labor and Education Policy in Comparative Perspective.

The faculty's accomplishments were reflected in various honors they received. Professor Cohen was awarded the Levitan Prize in the Humanities for his project, "The Moral Arc of the Universe: Justice and the Demise of Slavery." Professor Pye received the Graduate Student Council Teaching Award. The Canadian government named Professor Lincoln P. Bloomfield a member of the Canadian Institute for International Peace and Security. Assistant Professors Ellen Immergut and Richard Locke received research awards from a new German Marshall Fund program to encourage outstanding junior scholars to study Germany. Professor Stewart spent the year as National Fellow at the Hoover Institution.

Within the profession, MIT political scientists were highly visible. Professor Pye completed a term as President of the American Political Science Association. He is also a Director of the Association of Asian Studies, Vice Chairman of the National Committee on U.S.-China Relations, and Trustee of the Asia Foundation. Professor Hayward R. Alker, Jr. was elected Vice President of the International Studies Association. Professor Michael Lipsky serves on the Council of the American Political Science Association and on the Council of the Association for Public Policy and Management. He is also a member of the National Academy of Sciences' Committee on the Status of Black Americans. Professor George W. Rathjens chairs the Council for a Livable World. Professor Eugene B. Skolnikoff heads the Social Science Research Council committee on environment and security and serves on the National Academy of Sciences Global Warming Panel. Professor Suzanne Berger is a member of the Executive Committee of the Social Science Research Council.

Within the Institute, political scientists have served this year on the usual range of committees, but also have been involved in special initiatives ranging across many of MIT's activities. Professor Choucri has chaired an interdisciplinary faculty seminar on global environmental change. She is also co-chair of the Harvard-MIT Seminar on International Institutions and Global Environmental Change. Professor Berger continues to work on the dissemination of the findings of the MIT Commission on Industrial Productivity and counts eighteen lectures in 1989-90 on Made in America to groups as widely removed as the Northern Textile Association (Boston), the OECD, and the Mitsui Business Research Group (Tokyo). Professor Samuels heads the MIT-Japan Program, which now involves hundreds of undergraduates preparing for internships in Japan. Professor

Skolnikoff served on the Presidential Search Committee and chairs the committee to consider the implications of MIT's international involvements. Professor Samuels also belongs to the latter committee.

Beyond teaching, research, professional service, and Institute activities, many of the faculty participate actively in national and state policy analysis debate. Professor Meyer briefed President George Bush, Secretary of State James Baker, and Secretary of Defense Richard Cheney before the Malta Summit, and again before the May 1990 meeting with President Mikhail Gorbachev. He, as well as other faculty, testified this year before House and Senate Committees. Professor Sabel continues to work with the State of Pennsylvania on regional economic development. Professor Alker serves as a consultant to the UN Secretariat; Professor Immergut to the Spanish Minister of Health. By all counts, though, the most visible public figure in our faculty is Professor Bloomfield whose daily appearances on a Christian Science Monitor television program, Fifty Years Ago Today," are seen across the nation.

SUZANNE BERGER

Program in Science, Technology, and Society

The past academic year saw several advances for the Program in Science, Technology, and Society, as well as a continuation of intensive discussions of the place of STS at MIT.

THE DOCTORAL PROGRAM

In its second year, the Doctoral Program in the History and Social Study of Science and Technology fulfilled the promise of the first year. The new program, a collaborative venture with the History Faculty and the Anthropology/Archaeology Program, enrolled five outstanding new students this year and accepted four more for the coming fall. Graduate seminars were attended by students within the Program and by graduate students from elsewhere at MIT and from other institutions in the Boston area. Especially critical roles were played by Professors Merritt Roe Smith, Director of Graduate Studies and by Professors Jean Jackson of the Anthropology/Archaeology Program and Bruce Mazlish of the History Faculty, both of whom were members of the Graduate Program Steering Committee and taught required proseminars. The competitiveness of the program is witnessed by its continuing ability to draw a large number of outstanding applicants, and to attract students to MIT in the face of offers from other leading programs.

NEW PROJECTS AND GRANTS

The past year saw the receipt of more than \$2,500,000 in grants for new research projects and for the Knight Science Journalism Fellowship Program.

The Mellon Foundation made a grant of \$500,000 for the first three years of a five year study of the life sciences. Combining postdoctoral fellowships with international workshops and new graduate seminars, the study is intended to advance understanding of the contemporary biological and neural sciences; leading roles will be played by Assistant Professor Lily Kay and by Professor Charles Weiner. The STS Program was invited to seek an additional \$250,000 for the last two years of the project in its third year.

The MacArthur Foundation granted \$700,000 for a four-year series of Soviet-US Workshops on the broad theme of "Science and Technology with a Human Face." Focussing on such issues as the rise of environmentalism, the education of engineers, and the relationship of science and politics, the workshops will be held alternatively in Moscow and Cambridge: they will involve Soviet and American scholars and leaders concerned with the social implications of science and technology. The project is initiated and directed by Professor Loren Graham.

Three smaller grants were received. 1. GTE, as a part of its work in science, technology and ethics, will support special seminars during the Independent Activities Period on science, technology, and policy, led by Professor Leon Trilling and graduate student David Guston. 2. The Rockefeller Foundation made a grant to Professor Leo Marx to assist it in defining how the humanities and social sciences bear on environmental questions. Professor Marx is working with four STS graduate students in preparing a position paper. 3. An anonymous donor is supporting an archival and oral history study of MIT's efforts to bring the perspectives of the humanities and social sciences to bear on the understanding of science and technology.

The Knight Science Journalism Program, working closely with the Development Office, successfully raised its first match of \$300,000 and thus released the first \$1,000,000 of the Knight Foundation's \$5,000,000 endowment grant. Since that time, the Knight Program has received an additional \$100,000 from Arthur Vining Davis Foundations.

Finally, last year saw intensive discussions to work out the details of an affiliation between the Dibner Institute for the History of Science and the Burndy Library on the one hand and MIT on the other that would locate the Institute and Library on the MIT campus. It is hoped that a final memorandum of understanding will be developed in the summer of 1990.

STS AND POLICY STUDIES

Over the past years, the STS Program has been asked several times to discuss its "place" at MIT. One response of the STS faculty has been to seek permission to expand its current work in science and technology policy studies as a natural corollary of STS's commitment to the historical and social scientific study of science and technology. In September 1989, the report of the Committee on Restructuring Science, Technology, and Policy Studies at MIT (headed by Professor Joel Clark) proposed a close alliance between a new Science and Technology Policy Unit and STS. The STS faculty welcomed such an alliance in principle, but wished to be assured that the integrity of STS would be preserved in any new administrative arrangements. The nature of these arrangements was the topic of intensive discussions with the Dean and the Provost during the fall. In the event, however, no action was taken on the Clark Committee report.

THE SKINNER AND KENAN CHAIRS

The second topic of intensive discussions throughout the year was the disposition of the two senior chairs in STS vacated by the retirement of Professor Carl Kaysen (Skinner Chair) and Professor Marx (Kenan Chair) in June 1990. These discussions ended with the Provost's decision in early winter to authorize a senior replacement for Marx but not for Kaysen.

EDUCATIONAL ACTIVITIES

The bulk of the STS Program's educational work continues to be at the undergraduate level. Undergraduate enrollments were up, particularly as a result of the several HASS-D and Context subjects taught by Program faculty. In all, the Program offered 26 undergraduate subjects during the last academic year.

At the graduate level, four new graduate subjects were introduced. Of particular interest was a new student-initiated seminar offered by Professor Marx, Professor Keniston, and Dr. John Ehrenfeld of the Center for Technology, Policy and Industrial Development, which brought together graduate students from the Technology and Policy Program, Political Science, and STS in a discussion of the relationship between criticisms of technological society and the development of technology policy.

NEW PROGRAM INITIATIVES

The Program sponsored two major colloquia, on technological determinism and scientific misconduct. The first, led by Professor Smith and sponsored by the Dibner Institute, was on "Machines and History: The Question of Technological Determinism." It brought to MIT in a two-day conference during December more than a dozen scholars from across the country for a lively workshop whose proceedings are now being considered for publication by university presses. The second conference, on "Error, Fraud and Misconduct in Science," was organized in April by graduate students Guston and Eric Kupferberg and was co-sponsored by the Arthur Miller Lecture and the Context Initiatives Office. It brought to MIT historians, sociologists of science and policy-makers to consider historical and policy perspectives on scientific misconduct.

The Program this year initiated a series of STS Working Papers, which are pre-publication versions of studies by faculty and graduate students. So far, fourteen working papers have appeared, with another half dozen in preparation.

CONTINUING ACTIVITIES

The Program continued activities that had been initiated in earlier years. These include the Monday Lunch Seminars, led by Professor Kaysen; the monthly Faculty-Student Workshop, led by Professors Marx and Keniston; and the student-initiated Tuesday Lunch Workshops, organized this year by graduate student Kate Guan. The STS Newsletter, ably produced by staff member Graham Ramsay, continued with a revised format, featuring each month an introductory article of general interest followed by news and notes on STS faculty, staff and students.

FACULTY ACTIVITIES

The STS faculty continued high levels of professional and scholarly activity.

Associate Professor Louis Bucciarelli taught both in Mechanical Engineering and in STS; he is co-Principal Investigator in the development of a proposal from a coalition of MIT, Howard University, and other colleges to the National Science Foundation for new approaches to engineering education. Visiting Professor Jill Conway continues work on her book on the intellectual history of American feminism. Her book, *The Road from Coorain*, won the Winship Prize and was nominated for the Pulitzer Prize. Assistant Professor Deborah Fitzgerald's book, *The Business of Breeding: Hybrid Corn in Illinois*, was published this year by the Cornell University Press. She won a National Science Foundation Fellowship to begin work on Henry Wallace and was named Chair of the Program Committee of the Society for the History of Technology. Professor Graham's edited volume, *Science and the Soviet Social Order*, was published by the Harvard University Press; the Russian translation of his book, *Science, Philosophy and Human Behavior in the Soviet Union*, was published by the press of the Communist Party of the USSR. Assistant Professor Kay organized a new seminar on the history of the biological sciences for graduate students in microbiology. She was an invited Lecturer at the International Course in the History of Virology which was organized by the International School of the History of Biological Science, Naples, June 19-20, 1990. Professor Kaysen's article on the obsolescence of war appeared in the Spring 1990 issue of *International Security*; his activities included membership on the Advisory Board of the Institute for Scientific Interchange in Turin, Italy.

Professor Keniston wrote the introduction to *Living with AIDS*, published this year by the MIT Press, a volume that resulted from a collaboration between STS and the American Academy of Arts and Sciences. Professor Marx published articles on Lewis Mumford, on the American ideology of space, and on the future of pastoralism. He was elected a member of the Massachusetts Foundation for the Humanities, and gave the Richardson Lecture in American Studies at Georgetown. Professor Theodore Postol organized a new seminar series on Science, Technology, and National Security, jointly with the Kennedy School, and continued his work on the policy implications of modern military technology. Assistant Professor Lisa Rofel received an award from the Provost's HASS fund in support of her continued research on gender, ideology, industrialization and culture in contemporary Chinese society. Assistant Professor Rofel presented a paper as an invited talk at the Anthropology Department at Harvard University on "Gender and Subjectivity Among Contemporary Chinese Workers: Discourses of Resistance?" She published an article entitled "Hegemony and Productivity: Workers in Post-Mao China," in *Marxism and the Chinese Experience*, edited by Aris Dirlik and Maurice Meisner. Professor Smith was named Metcalfe Professor of Engineering and the Liberal Arts. He is President of the Society for the History of Technology and became co-Director of the Context Initiative at MIT. He published articles on "Technology, Industrialization and the Idea of Progress in America," and on the early history of American engineers. He has been appointed Series Editor for the Johns Hopkins University Press. Professor Trilling taught both in the Department of Aeronautics and Astronautics and STS; he organized and led a faculty seminar on the impact of changes in Europe on military support of research, and will edit an issue of *The Weaver* on space policy. Associate Professor Sherry Turkle last year published widely on the meanings and implications of computation; she is continuing her study of computers and education in the USSR, funded by the MacArthur Foundation. She was a member of the MIT Committee on Academic Computation for the 1990s and Beyond and received an Honorary LL.D. from Claremont University Center and Graduate School in May 1990. Professor Weiner lectured widely on social and ethical aspects of biotechnology, and continued work on his book on the ethical dilemmas of biologists.

KENNETH KENISTON

Center for International Studies

OVERVIEW

During the academic year 1989-90, the activities of the Center for International Studies reflected the rapid changes in the world arena in such fields as defense and security, development, environmental concerns, and population movements. These concerns were addressed in new and on-going seminars sponsored and co-sponsored by the Center, in the publications of the CIS-affiliated faculty, and in the new biannual CIS new letter, *Précis*.

SEMINARS AND WORKSHOPS

The themes of CIS Seminars during 1989-90 addressed issues, among others, of persisting poverty in the Third World, democratization in developing areas, ethnic conflict, increasing problems of international migration, and global environmental change. One of the best attended seminars has been the 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). The Seminar focuses 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 26th) "Democratization and Development." Co-chaired by Professor Myron Weiner, Director of CIS, and Professor Jorge Dominguez of the Center for International Affairs at Harvard, the Seminar examined the theoretical dimensions of the democratization process in the Middle East, Latin America, Asia (Taiwan, South Korea and India), and Eastern Europe. A new seminar, Peoples and States, chaired by Professor Jean Jackson (Anthropology/Archeology), examined the relationship of Ethnicity, Ethnic Conflict and the State. Among the cases discussed were those of India, Southern Africa, Rumania, Guatemala, and Brazil. The Inter-University Seminar on International Migration, in its 10th 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, United States immigration policies. 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 South Asia Seminar, jointly sponsored by MIT, Harvard, and Boston University, continued to bring together Boston area scholars for discussion and analysis of issues related to South Asia. Two new series, 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 is covered also in the ongoing Emile Bustani Seminar, chaired by Associate Professor Philip Khoury (History Faculty). Finally, the new MacArthur Graduate Student Seminar, organized and chaired by Dr. Elizabeth Leeds, Assistant Director of CIS, brings 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 the implications for United States defense politics; another chaired by Associate Professor Stephen Meyer focuses on Soviet security policy; a third led by Associate Professor Barry Posen examines the conventional forces balance; a fourth headed by Professor Theodore Postol considers trends in weapons technology; a fifth jointly managed by Professor Sapolsky and Associate Professor Meyer of the DACS Program and Associate Professor Richard Samuels of the MIT Japan Program focuses on security relations in the North Pacific; and a sixth run by Professors George Rathjens, Jack Ruina, and Carl Kaysen explores implications for United States security policies. In addition, the Program sponsored four seminar series --the traditional DACS Seminars; a series on Technology jointly offered with the Kennedy School at Harvard; a faculty series on Civil/Military Relations chaired by Professor Leon Trilling; and a series on Defense Research and Development Policy organized by Professor Ruina.

The new 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: *DACS Facts*, the Program's newsletter, in addition to *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. Six visitors, including several pre-doctoral candidates from other institutions, were with the Program during the year.

MIT JAPAN PROGRAM

The MIT Japan Program has continued to expand in the numbers and fields of interns sent to Japan, by the scale of support of the Program's benefactors, and in research activities undertaken. Forty-three year-long interns were sent to Japan in a wide range of industrial sectors in 1989-90. More than 50 have been placed for 1990-91. In a joint initiative with the Sloan School of Management, the Program will send seven management interns to Japan in the fall of 1990 to work in Japanese financial institutions, consulting firms, and industry. The Technical Japanese Language Project, now in its third year, is a highly competitive advanced summer reading course for computer scientists and engineers. Taught by Professor David Mills of the University of Pittsburgh, the Project plans a similar course for materials scientists in the summer of 1991.

Research activities in the past year include hosting, in Hawaii, the first workshop of the Japan-US Joint Study Group in Trade, Finance, and Technology in East-West Economic Relations. The meeting was attended by academics and businessmen who examined shifts in East-West economic relations, and their implications for international security, technology transfer, and financial relations. The Program has also contributed to an interim report of the Office of Technology Assessment, "Arming our Allies: Cooperation and Competition in Defense Technology." The study examines U.S. policies regarding collaboration in weapons production with NATO and Japan in the postwar era. Associate Professor Samuels, Director of the Program, is carrying out research on the changing relationship of the civilian and military economies in industrial democracies with specific reference to Japan. Michael Chinworth, Director of Research, is studying first, the direction of Japanese defense procurement policies in an era of global trends to cut back on defense spending, and second, United States defense industry diversification and the role of Japanese technological innovation in that process. The wide range of the Program's research interests is reflected in the fifteen working papers produced in the past year.

Corporate, foundation, and alumni support for the Program has expanded markedly this past year. The Program received a two million dollar grant from the Starr Foundation, complementing previous Starr support dating from 1985. A generous gift was made by Dr. Yaichi Ayukawa, MIT alumnus and life member of the MIT Corporation. Support continues from the Japan-US Friendship Commission, the Hitachi Foundation, and the National Science Foundation, as well as from U.S. corporate sponsors.

SEMINAR XXI PROGRAM

Under the auspices of CIS and the direction of Professor Suzanne Berger (Political Science), the Seminar XXI Program recently completed its fourth year. "Seminar XXI: Foreign Politics and the National Interest" is an educational program for senior military officers, government officials and industry executives of the national security community. The seminar meets monthly in Washington, DC, with each session focusing on different frameworks for analyzing the politics of foreign countries. The aim of the program is to develop among the fellows new analytic skills for understanding foreign societies. By widening the range of possible explanations for the behavior of United States allies and rivals, the range of policy options which can be considered systematically is also expanded. With the upheavals in the communist world and other radical changes in world politics over the past year, there is a premium in the United States policy-making community on the kinds of critical and innovative thinking about United States foreign relations and developments in foreign societies that Seminar XXI attempts to foster. Funding from private foundations and a generous gift from Mr. Harry Kalker (MIT '23) provided financial support for the development and expansion of the program in its early years. The program is now self-supporting, with participating organizations paying a fee for each fellow involved.

OTHER ACTIVITIES

CIS was host, during 1989-90, to 22 visiting scholars from the United States, India, Brazil, Taiwan, Italy, Germany, and England. The Center sponsors and administers three annual competitions: the MacArthur graduate student grants for pre-doctoral research in development and defense/security studies; the Japan Endowment Fund for research in international energy with particular attention to environmental and security issues; and, in cooperation with Political Science and UROP, a summer grant for undergraduates to carry out research abroad. Five newsletters are currently being produced by the Center and Center programs: *Précis*, the Center newsletter (published biannually), the *Asian Council Newsletter*, *Soviet Defense Notes*, *DACS Facts*, and the *Japan Program Newsletter*.

ELIZABETH LEEDS

Center for Materials Research in Archaeology and Ethnology

There was a Latin American spirit at the Center for Materials Research in Archaeology and Ethnology during the 1989-90 academic year, as CMRAE hosted three visiting scholars from the research laboratory of the Museo Antropologico del Banco Central del Ecuador, Guayaquil. The Center received a \$49,000 grant from the J. Paul Getty Trust Grant Program in support of the three scholars, who joined CMRAE under a long-term cooperative research agreement entered into by the Banco Central del Ecuador and CMRAE in 1984. The research program, directed by Assistant Professor Dorothy Hosler (Anthropology/Archaeology Program and CMRAE), involves a comprehensive technical study of the prehistoric metallurgy of Ecuador, from the ore sources used to smelt metals to the possible long-distance maritime exchange of alloys. In addition to their metallographic studies of artifacts from the Guayaquil museum's collections, each scholar participated in a conservation/museum environment internship program at one of the three museum laboratories that are members of CMRAE: the Research Laboratory, Museum of Fine Arts of Boston; the Conservation Laboratory, Peabody Museum of Archaeology and Ethnology, Harvard University; and the Center for Conservation & Technical Studies, Fogg Art Museum, Harvard University.

In 1989, after three years of rewarding field and laboratory research sponsored by the Getty Grant Program, the four participants in CMRAE's ambitious project *Style in Art and Technology* dispersed to their several institutions. Shortly thereafter, the Center received an invitation from the College Art Association to present a Board-sponsored panel on the project's theme and results at the 1991 annual meeting of this professional society for art history. The invitation is particularly welcome, since one of the goals of the research program was to bring the perspectives and methods of the Center before the art historical public.

After a hiatus of several years, the Center reconvened its popular Materials and Anthropology discussion series, begun in 1967 by Institute Professor emeritus Cyril Stanley Smith. The speakers, anthropologists, archaeologists, and materials engineers, discussed topics that ranged broadly from the iron currencies of S. Cameroon to the isotopic biochemistry of prehistoric diets. Assistant Professor Hosler spoke about her research with the potters of a small South American community and their reinvention of an ancient ceramic technology. Dr. Michael Geselowitz (CMRAE) is coordinator of the M & A series.

Assistant Professor Hosler, together with Professor Heather Lechtman (Anthropology/Archaeology Program and Materials Science and Engineering), published a major monograph on the axe-monies of ancient Mexico and Ecuador as the latest number in the *Dumbarton Oaks, Harvard University research series in Pre-Columbian Art and Archaeology*. This detailed technical and ethnohistoric study documents what may have been the first metallic primitive money system to be developed in the ancient New World.

The Center's two-semester graduate subject for the 1989-90 academic year, taught by Professor Lechtman and Dr. Geselowitz, was *Materials in Ancient Societies: Metals*.

HEATHER LECHTMAN

Integrated Studies Program

ISP is one of the three alternative programs for freshmen at MIT. We offer an exciting and stimulating way for students to fulfill their freshman science requirements while at the same time providing the advantages of a small, supportive academic community. The program emphasizes 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.

ISP enrolled 36 students this past fall, one above our enrollment goal of 35, and an increase of 15 over our fall, 1988, enrollment. Of this group, 15 were female and 10 were members of minority groups. We enrolled 25 students in spring (7 female and 8 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, this fall we offered the new experiment-based physics course, 8.01X, team-taught by Professors John G. King and A. P. French. In spring, for the second year, ISP students enrolled in 8.02X. Both physics subjects augmented lectures and recitations with vital laboratory components.

At the heart of ISP are the two humanities courses, "Technologies and Cultures," offered in fall, and "Technologies in Historical Perspective," offered in spring. These courses are team-taught, principally by a humanist and a technical instructor, with the addition for the first time this spring of a physicist. Through a variety of readings, writing, and class discussion, students studied 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 these technologies supplemented the regular ISP faculty and staff as workshop facilitators.

In keeping with ISP's commitment to expose students to a wide range of ideas, we inaugurated a weekly luncheon seminar series this year. In these luncheons, students met a variety of MIT faculty and staff and others.

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 spring humanities course.

Dr. Jim Livingston, Lecturer in the Department of Materials Science and Engineering, taught the 3.091 recitation, and Chemistry graduate student Patti Christie taught our 5.11 section. Steve Fromm, a graduate student in the Math Department, taught the calculus recitations both semesters. We appreciate their enthusiasm and dedication. Christopher Craig, Technical Instructor in ISP, developed 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 was a welcome addition to the ISP staff this year as Program Administrator.

Arthur Steinberg, Director

Women's Studies

CURRICULUM

In 1989-90, its sixth year of operation, the Program in Women's Studies saw a significant increase in curriculum offerings over the previous academic year. Eighteen subjects and one undergraduate seminar were offered, with roughly 350 students taught. Especially noteworthy was the Program's expansion of its graduate-level curriculum; graduate credit was available for four Women's Studies subjects: Gender, Social Change and Planning (joint-listed with the Department of Urban Studies and Planning {DUSP}); Gender Work and Politics (joint-listed with the Program in Science, Technology and Society {STS}); Women and Computers (joint-listed with STS); and a new course, Women and Children in the Legal System (joint-listed with Political Science). The latter is the first Women's Studies subject to be cross-listed with the Department of Political Science -- a move which had been under discussion for several years -- and was taught by Visiting Lecturer Margaret Burnham, a prominent Boston lawyer. Other subjects inaugurated during 1989-90 included: Representations of Women in 19th C. Culture (joint-listed with the Program in History, Theory, and Criticism in the Department of Architecture); Gender and Ideology in 18th C. Literature (joint-listed with Literature); Women Novelists Since World War II (joint-listed with Literature); and the undergraduate seminar Life Issues for Professional Women.

Additionally, several new subjects developed this year will be offered during Academic Year 1990-91. Assistant Professor Lisa Rofel's course entitled Gender, Science, and Technology (joint-listed with both Anthropology and STS), will provide students with an opportunity to review the now extensive literature in this thriving field, and will advance the Program's objective to seriously engage with the intellectual "heart" of the Institute: science and engineering. Modernism and Sexuality, to be taught by Assistant Professor Leila Kinney (Department of Architecture) will examine the formidable new scholarship in feminist film theory, representation, gender and sexual difference. Desire and Discourse: Introduction to Lesbian and Gay Studies, to be co-taught by Professor David Halperin (Literature) and Lecturer Joni Seager (Women's Studies), will be the first fully-credited subject at the Institute to undertake the new multi-disciplinary research on the theory and practice of gay and lesbian studies. Visiting Assistant Professor (History) Sherifa Zuhur's course, Unveiling Eve: Women's History in the Middle East, will offer critical perspectives on the status of Middle Eastern women often rendered invisible in the academy. And finally, an undergraduate seminar on Women and the Health Care System will provide a socio-historical overview of the medical establishment's impact on women's lives. In July 1990, Professors Ruth Perry and Susan Carey and Associate Professor Isabelle de Courtivron will be offering a new, and instantly oversubscribed, MIT summer session course, "Women and Work: What Difference Does Gender Make?"

STUDENTS

Confluent with the Program's growing emphasis on graduate study, a Graduate Student/Faculty Luncheon Seminar Series was implemented 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 such subjects as women in Nigeria; skill polarization in the nursing profession; women and the Palestinian Intifadah; gender bias in science; and current theories in equality law.

Since the Women's Studies minor was instituted last year, four students have graduated with that designation, and seven other students are currently pursuing completion of minor coursework. Concentration figures have risen slowly, but steadily; twelve 1990 graduates had concentrated in Women's Studies, with fifteen current underclassers already declared.

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, and this year's events were particularly varied and lively. Visiting Professor Frances Stubbs' course on Black Women Writers brought to campus the renowned novelist and poet Margaret Walker, as well as two important Black feminist literary critics, VeVe Clark and Clyde Taylor. The third annual Women and Politics Series, co-sponsored by the Department of Political Science and the Center for International Studies (CIS), featured talks by Professors Claudia Koonz (Duke Univ.), Jane Mansbridge (Northwestern Univ.) and Susan Okin (Brandeis Univ.). Professor Bina Agarwal of the Institute of Economic Growth at the Univ. of Delhi in India delivered a lecture as part of the DUSP Special Program for Urban and Regional Studies. Women in International Development and CIS co-sponsored a talk by Afro-Brazilian community organizer Joselina da Silva. A forum on grass-roots community organizing among Latin American women included speakers from Nicaragua and Costa Rica. Honor Ford-Smith, founder and director of Sistren: Jamaican Women's Theatre Collective, spoke on the politics of development and its impact on cultural work, co-sponsored by the Theatre Arts Program, the Literature Faculty and CIS. Professor Nicole Ward Jouve (Univ. of York,

England) presented her analysis of a case in which two French maids murdered their employer, in a talk entitled "Women Who Kill." During IAP, the Program coordinated a program of three speakers presenting new scholarship on Asian women, which was amplified by a film/lecture series on women throughout Japanese history. Also during IAP, the Program co-sponsored several films by and about lesbians as part of series organized by the Committee on Gay and Lesbian Studies at MIT. A lecture/recital on women in music was presented by music historian Barbara Englesberg. Film-maker/historian Alia Arasoughly's February talk on "Sexuality and Nationality in New Egyptian Cinema" inspired a group of Arab women students to approach Women's Studies for help in organizing a film festival on Women in the Arab World. This event was held in April and was extremely popular, particularly among Arab students and staff. And finally, feminist elder stateswoman, Adrienne Rich, read her poetry to a monumentally oversubscribed audience as part of the Poetry at the Media Lab series. The Program in Women's Studies is often cited by those in the larger Boston academic and feminist communities for the range and diversity of its programming.

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. Dr. Elizabeth Potter, whose research is in the philosophy of science and gender, joined the Program this spring as a Visiting Scholar. Dr. Potter is working on a book to be entitled "Gender Politics in Seventeenth-Century Science."

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 Robin Becker's new collection of poems, Giacometti's Dog, was published by Univ. of Pittsburgh Press. Among her articles, Professor Susan Carey has an article entitled "Teaching for Understanding in the Age of Technology." Dialectical Anthropology published Professor Jean Jackson's "Is There a Way to Talk about Culture without Making Enemies?" Assistant Professor Leila Kinney has articles in press for two prestigious journals, French Politics and Society and October. Visiting Assistant Professor June Namias' book, White Captives: Gender and Ethnicity on Successive American Frontiers, 1607-1862, is forthcoming. Professor Ruth Perry edited a special issue of Signs: Journal of Women in Culture and Society on women and computers, also forthcoming. Assistant Professor Lisa Rofel, who joined the Program this year, has just published an article "Workers in Post-Mao China" in Marxism and the Chinese Experience, edited by Dirlik and Meisner. Lecturer Ann Russo has published numerous articles this year and has two forthcoming books, Third World Women and the Politics of Feminism, and The Radical Women's Press of the 1850s, both co-edited. Associate Professor Sherry Turkle published "Epistemological Pluralism: Styles and Voices within the Computer Culture" in Signs. Senior Lecturer Caroline Whitbeck presented a lecture entitled "Gender, Technology and Empowerment" at Princeton and authored "The Effects of Technology and Pharmacology on Women's Health" which will be published in the forthcoming volume Reproductive Technologies: Multidisciplinary Perspectives, edited by Judith Rodin.

BARBARA SCHULMAN
SANDY MARTIN

SLOAN SCHOOL OF MANAGEMENT

Globalization was the main theme during the Sloan School's 1989-90 school year. Our master's students arranged a visit to Japan and Korea. Our links to STOA, a new Italian business school, became fully operational with some of their faculty spending time here and some of our faculty spending time there. The MIT-Japan program was expanded to include management students. An agreement was made with Nanyang Technical University in Singapore similar to the agreement concluded with STOA. Some of their faculty will spend some time here; some of our faculty will spend some time there. Joint with the school of humanities and social sciences committees have been set up to investigate master's level MBA-Regional Studies programs. Meetings were held to expand our long-standing exchange programs with the Soviet Union.

In a departure from our normal practice we have begun experimentation with company-specific executive education programs. In the past we have resisted these programs on the grounds that students learn from each other and that there is a benefit to having people from different companies in the same classroom. If one teaches that one should get close to one's customers, however, one has to practice what one preaches. Our customers want company-specific programs and we are learning how to make them work.

TEACHING PROGRAMS

Undergraduate Program

During the 1989-90 school year, 51 seniors majoring in management science were graduated. Of those 51 seniors, 12 chose an option in marketing research, 11 selected behavioral science, nine concentrated in information technologies, and two in operations research. Of the remaining 17 students who were pursuing other specially approved subjects, 13 chose an option in finance.

Six of our graduates also received bachelor s degrees from other departments: two from the Department of Electrical Engineering and Computer Science, and one each from the Departments of Economics, Mathematics, Mechanical Engineering, and Political Science. Two students received simultaneously the SB degree in Management Science and the SM degree in Management; and one student received simultaneously SB degrees in Management Science, Biology, Electrical Engineering and Computer Science, and the SM degree in Management.

This May the department was pleased to acknowledge two exceptional students in management science. Anne T. Law and Gayle T. Tomita 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.

Since the introduction of the new management science curriculum six years ago, the undergraduate enrollment at the Sloan School has been increasing. Although a record number of seniors were graduated this year, the overall undergraduate enrollment now appears to be levelling off.

This spring 117 students were enrolled in the Management Science Program, including 12 who were enrolled in management science as their second SB department. (Enrollment figures are based on the registrar's fifth week counts.)

Sixty of our continuing undergraduates have declared their options as follows:

Regular Options

Information Technologies	19
Marketing Research	10
Behavioral Science	7
Operations Research	2

Special Options

Finance	19
International Management	2
Operations Management	1

A large number of students from other MIT degree programs continue to enroll in our undergraduate subjects. There were 445 such enrollments during the 1989-90 academic year, representing the classroom equivalent of 48 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 80 additional undergraduates in our program, for an equivalent total of 197.

Faculty serving as undergraduate advisors were Professors Thomas J. Allen, Ravi Bhushan, Steven D. Eppinger, Robert M. Freund, Stephen C. Graves, John C. Henderson, Rebecca M. Henderson, Peter J. Kempthorne, James B. Orlin, and Michael A. Rappa, along with Dr. Jeffrey A. Meldman, Director of Undergraduate Programs, Mr. David R. Breakstone, and Ms. Hillary De Baun, Program Administrator. Professor Anant Balakrishnan became 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.

Faculty serving on the Undergraduate Policy Committee included Professors Allen, Freund, Orlin, John Henderson, and ex offiis, Dr. Jeffrey A. Barks, Dr. Meldman, and Ms. De Baun. Professor Gordon M. Kaufman served as committee chair.

During January 1990 we offered our IAP activity "Organizational Reality" for the second 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 also involved the coordinated participation of 13 management faculty, a panel of mid-career students in our Management of Technology program, and two MIT alumni from the corporate sector.

Twenty-four 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, Deborah G. Ancona, Lotte Bailyn, John S. Carroll, Thomas A. Kochan, Lisa M. Lynch, Thomas W. Malone, Stewart C. Myers, Edward B. Roberts, Abraham J. Siegel, Robert J. Thomas, and Doctors Jeffrey A. Meldman and JoAnne Yates.

Management faculty who participated in other IAP programs were Professor Kenneth A. Froot who, with Professor R. W. Dornbusch of the Department of Economics, held a full-day session on Japanese trade; Dr. Jeffrey A. Meldman and Professors Judith A. Lachman and J. D. Nyhart who conducted sessions in the series "A Brief Introduction to Law;" Professor Donald R. Lessard who coordinated the Bourse Game seminar in conjunction with Citibank; and Dean Lester C. Thurow who participated in a panel discussion that addressed the question "Is The Arms Race Winding Down?"

Throughout the year members of our faculty contributed to the undergraduate educational commons in the following ways: Professor Stuart E. Madnick served as faculty liaison to the Institute Admissions Office, in addition to reading freshman applications. Professors John D. C. Little, Richard M. Locke, and Karl T. Ulrich were engaged in freshman advising, and Dr. Meldman also advised freshmen and conducted a freshman advisor seminar for his advisees; Professor Edward B. Roberts conducted an undergraduate seminar on starting a business. Six of our faculty served on institute committees concerned with educational policy and programs: Professor Henry D. Jacoby served his first year as Chair of the Faculty; Professor Lotte Bailyn served on the Faculty Policy Committee; Professors Arnold I. Barnett and John S. Carroll served on the Student Affairs Committee; Professor Paul Osterman chaired the Library Systems Committee; Professor John Sterman served on the Committee on Curricula, and Professor N. Venkatraman on the Committee on the Writing Requirement. Twenty-seven faculty supervised UROP projects for students from departments throughout the Institute.

Master's Program

In the spring of 1989, a major reassessment of the core curriculum resulted both in revisions of the standard core courses and in the creation of a series of integrative exercises, intended to combine material across course lines. This year those changes were incorporated and the second of these exercises, a four-section module on technology management, was implemented. The module was quite successful, and further integrative projects are currently being designed.

The Leaders for Manufacturing Program completed its first full cycle, with 20 students graduating after a rigorous 24-month curriculum. The combination of classwork and a six-month internship has proven quite successful. Class of 1991 students are currently on-site for internships with the eleven sponsoring companies, and 35 new students have just joined the growing program.

Key figures from the world of business continued to share their expertise with the Sloan community. Colby Chandler, Chief Executive Officer of Kodak, headlined a blue-ribbon panel for the Business Forum's fall presentation on America's Competitive Challenge in the '90's. The spring presentation, on federal industrial policy, featured such noted speakers as Congressman Edward Markey. The Distinguished Speakers Series brought to Sloan Christie Hefner, President and Chief Executive Officer of Playboy Enterprises, Inc.

This year marked the inauguration of the Alumni/ae Award for Excellence in Management, a teaching award voted on by the entire master's student body. Professor Paul Asquith was recognized for this honor at Faculty Appreciation Day, an annual tribute and celebration organized by the Graduate Management Society. Professor Stuart Madnick was again the Sloan School winner of the MIT Graduate Student Council Teaching Award (he is the first repeat winner, having also received the award in 1987).

Several second-year master's students were awarded merit scholarships on the basis of academic excellence and professional promise. The Miriam Sherburne Scholarship, established by the alumni/ae of the school in recognition of Ms Sherburne's more than 50 years of devoted service, was given to Amelie L. Ratliff. Nick J. Pudar was chosen as the Henry P. du Pont III Scholar. This annual award was established by the Crestlea Foundation with a gift from the late Mr. du Pont. The Henry Ford II Scholarship, established by the Ford Motor Company in 1978, was presented to Thomas J. LeFevre. Juliet A. Sears was named the George Henning Scholar. This scholarship was established in 1988 by the Henning family. The Thomas M. Hill Prize for best student in accounting went to T. Louis Gutierrez. This award was established by the late Professor Hill's friends and colleagues to honor his memory and his 30 years of distinguished service to the school.

Antonio M. Parham and Julie A. Schwartz were named the 1989-90 Seley Scholars, awards established by the late Mr. and Mrs. Louis F. Seley to honor graduating master's students for outstanding academic achievement, exceptional promise of business leadership, and contribution to the MIT/Sloan community.

The Junior Achievers Fellowships, sponsored by the Little Family Foundation to support management education for people who developed an interest in business through the Junior Achievement program, were awarded to Thomas Anderson, Albert Chen, Stanley Fung, William Heflin, Daniel Mayo, and Laura Ring. Jeffrey Cheung was awarded the Procter and Gamble Company scholarship for international students.

One of Sloan's over twenty student clubs, the New Venture Association, was awarded the William I. Stewart Jr. award by MIT for contribution to the extracurricular life of the school. The NVA, which promotes interest in entrepreneurial activities, works with the MIT Technology Licensing Office to help MIT inventors bring their products to market. They also established the 10k Entrepreneurial Contest to recognize and support student business plans.

Thirty-five second-year master's students took a ten-day study tour of Japan and Korea, visiting businesses and learning about corporate and cultural life. The trip included a series of pre-trip lectures and classes to prepare the students for their visit. While in Korea and Japan, the students were hosted at a number of events by Sloan alumni/ae.

Applications for admissions increased this year, providing an even larger and more competitive pool. The entering class in September numbered 245, including LFM students.

The following table presents a profile of the graduate classes of 1990 and 1991:

<i>Profile of Graduating Master's Classes</i>	1990	1991
Number of Candidates:	202	245
US Citizens	129	160
Foreign Citizens	73	85
Women	41	57
Members of Minority Groups	14	30

<i>Profile of Graduating Master's Classes (continued)</i>	1990	1991
Median GMAT score (national average is approximately 460)	655	650
Undergraduate Grade-Point average (out of 5.0)	4.5	4.5
Undergraduate Majors:		
Social Sciences and Humanities	35%	31%
Physical Sciences	12%	12%
Engineering	44%	48%
Pre-Professional	9%	9%
Average Years Full-Time Work Experience	3.0	4.0
Age at Admission:		
Under 23 years	8%	2%
23-24	21%	17%
25-26	29%	36%
27-28	22%	19%
29 and over	20%	26%

*Projected

Career Development Office

Signs of a softening economy, evident last year by the end of the placement season, continued through 1989/90, with definite impact on MBA employment opportunities and students' job hunting activities. Despite a 5% rise in the number of companies making fall semester presentations (up to 84 firms) and optimism expressed by the typically aggressive MBA recruiters, an overall mood of conservatism prevailed throughout the spring. Year-end statistics show a 9% drop from 1989 figures in the number of firms interviewing Sloan candidates in 1990.

Within this conservative hiring climate, students did surprisingly well in securing excellent jobs. Candidates successfully marketed themselves to potential employers, as evidenced by the breadth and responsibility levels of the final positions offered to Sloan graduates. Students' success in the job market is also demonstrated by the 5-7% increase over 1989 figures in starting base salaries paid to graduating class members.

Looking back on the experience, students realize they gained more than just exciting work opportunities from their demanding job campaigns. Candidates learned many valuable lessons from assessing individual strengths and interests, setting personal goals, and promoting themselves to firms which interested them. In the final analysis, the competitive job market forced students to hone important skills which should prove central to personal and professional development in the future.

Preliminary placement statistics for 1990 reveal that the single greatest shift compared with last year's graduates came in the number of students entering consulting (up to 34% from 24% in 1989.) Two other noteworthy shifts were the decrease in students entering electronics/computer firms (down from 16% to 11%) due to the market slump, and the number of students entering the manufacturing sector overall (down from 35% to 29%).

Placement statistics sorted by the job function students selected reveal an increase from 25% to 37% in students entering consulting positions, a decrease from 28% to 18% in students entering finance roles, and a decrease from 21% to 11% in individuals taking marketing jobs. The downward shift in students entering financial positions stems from a decrease in candidates taking jobs with both commercial banks and corporations (students entering investment banking remained the same at 12%). In the case of marketing roles, the decrease appears related to reduced hiring by high tech firms this season.

On average, members of the Class of 1990 received three job offers. From these opportunities, graduates selected positions at starting base salaries ranging from \$32,000 - \$141,000. Median salaries paid by different industries ranged from \$53,000 - \$68,000. More detailed information on this year's market, students' career decisions, and salaries paid to Sloan candidates will be available later this summer from the Career Development Office in their year-end placement report.

Alumni/ae Relations

The alumni/ae relations program continued to work toward providing two main emphases: the social, academic, and professional benefits our graduates expect from their school; and the wealth of resources and business world connections that support Sloan.

The Board of Governors for the Master's Alumni/ae met in both the spring and the fall this year, focusing their efforts on defining the roles of alumni/ae and school in such areas as communications, continuing education, fundraising, and spirit-building. Regional Sloan Clubs offered a variety of activities, including hosting breakfast series, social events, and formal presentations by Dean Thurow. Alumni/ae actively supported the school through participation in fundraising telethons, which raised over \$55,000--the highest dollar amount of any of MIT's telethons this year. Alumni/ae also played a crucial role in the admissions recruitment evenings held throughout the US and in key European cities.

Reunion was held the weekend of June 9 and 10, honoring the master's classes of 1965, 1970, 1975, 1980, and 1985. Softball games, picnics, and a harbor cruise were the class-specific options, with a Saturday night reception and dinner drawing the largest crowd in Sloan history.

The Tenth Annual Summer Gatherings were held in New York and Boston, with San Francisco and Washington gatherings scheduled in the next few months.

Alfred P. Sloan Fellows Program

On June 5, 1990, 56 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1990 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 58th 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 Thailand, Hong Kong, and Japan.

	81-2	82-3	83-4	84-5	85-6	86-7	87-8	88-9	89-90
<u>Industry</u>									
United States	30	28	26	30	26	31	33	25	26
International	15	13	15	13	12	14	12	20	19
<u>Government</u>									
United States	7	10	8	9	10	8	7	6	7
International	0	2	5	3	4	0	4	3	2
<u>Other</u>									
World Bank	0	0	0	0	0	0	0	0	1
Municipal Mgt	0	0	0	0	1	1	0	0	0
Medical Mgt	4	3	4	3	2	0	0	0	1
Church Mgt	0	0	0	1	0	0	0	0	0
<u>University Mgt:</u>									
United States	1	1	1	1	1	1	0	0	0
International	0	0	0	0	0	0	0	0	0
	55	55	56	57	54	55	56	54	56

The demand for the program continues to be strong and the quality of the nominations is extremely high. On June 5, 1990, the Class of 1990-91 arrived; there are 58 participants in the 1990-91 program.

The Director of the Sloan Fellows Program, Alan F. White is an alumnus of the program (Class of 1971). Professor Robert McKersie served as Chairman of the Faculty Program Committee.

Program for Senior Executives

The MIT Program for Senior Executives continues to attract outstanding candidates from around the world. The program focuses on major current concerns of senior management, including global competition, rapid technological change, and effective human resource management.

The MIT Society of Senior Executives, consisting of alumni/ae of the program, has scheduled its second convocation for October 18-20, 1990 entitled "New Parameters: Business in the 21st Century." The convocation will address recent economic, social and political events, and changes in the critical forces affecting the operating parameters and structure of business. Featured speakers are: former Swiss President Dr. Kurt Furgler; East German economist Dr. Gunter Notzold; Executive Vice President Philip Condit of the Boeing Commercial Aircraft Group; and, a number of outstanding MIT faculty including Nobel Laureate Paul Samuelson and Sloan School Dean Lester Thurow.

In June of 1990, Professor John Van Maanen assumed responsibilities as Chairman of the Faculty Committee, temporarily replacing Professor Michael Scott Morton who will be on sabbatical leave during the academic year 1990/91. At the same time, Dr. Peter Gil assumed the position of Director of the Program, taking over from Dr. Charles Grader, who became Director of the Sloan Fellows Program. Dr. Gil has previously served the school as Associate Dean, Director of the Sloan Fellows Program and, most recently, Director of the Management of Technology Program.

Sloan continues to expand its alumni/ae relations effort, recognizing the tremendous mutual value of the relationship between graduate and school.

Management of Technology Program

The MIT Management of Technology Program (MOT) was established in 1981 and is the only program of its kind. Administered by the Sloan School of Management and the School of Engineering, this 12-month, full-time program leads to the degree of Master of Science in the Management of Technology. It is aimed at engineering and science managers with five to ten years of work experience, and strives to prepare them for more senior roles in industry and government where they will assume leadership positions in the creation and growth of technology-based endeavors.

Until April, Dr. Peter P. Gil served as acting director of the program; at that time Roger Samuel assumed the directorship. Professor Thomas H. Lee of the Department of Electrical Engineering and Computer Science and Professor Edward B. Roberts of the School of Management served as faculty co-chairs.

Applications for the class of 1990-1991 reached an all-time high; enrollment reached a new high of 44 students. A strong marketing campaign continues as the program builds towards its ultimate goal of 55 students.

A thorough review of the MOT curriculum was conducted by the associated faculty; numerous improvements will be introduced beginning in the fall 1990 term. Among the most noteworthy are: the addition of a project management course taught by Professor Ernst G. Frankel of Ocean Engineering; the addition of a finance course taught by Professor Frank J. Fabozzi; a new cornerstone course on managing technology developed by Professor James M. Utterback; and a new elective in negotiation, limited in enrollment to MOT students and Sloan Fellows, taught by Professor Robert B. McKersie. In addition, there has been a doubling of the number of manufacturing courses from which the MOT students can choose in satisfying their requirement in that area.

The PhD Program

During 1989-90, 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 349 applications, we made 27 admission offers and had 18 acceptances, distributed across 12 concentrations:

Finance	2 (2 foreign males)
Industrial Relations	1 (US female)
International Management	2 (1 US female-1 "underrepresented" minority, and 1 foreign male)
Management of Technological Innovation	2 (1 US female, 1 US male)
Organization Studies	2 (2 foreign males)
System Dynamics	1 (US female)
Strategy & Policy	1 (foreign male)
Information Technologies (formerly MIS)	4 (3 US males, 1 US female)
Marketing	1 (foreign male)
Operations Management	2 (2 US males)

The overall percentage of US applicants remained at 38% and the foreign applications at 62% while still reflecting 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 five MIT Special Summer Program courses. Four of these were of one-week duration (Marketing; Systems Dynamics; Models, Parallel Computing and Expert Systems; Information Processing Tools and Techniques). The fifth course, Management of Research, Development, and Technology Based Innovation was of two weeks duration. It continues to be heavily over-subscribed by senior professionals in the R & D field.

In addition to the MIT Special Summer Program courses the Sloan School offered five one-week programs: two that have been available for several years (Corporate Strategy; and Financial Management) and three experimental, first-time seminars: Complex Organizations; Japanese Technology Management and Management Issues for Corporate Counsel. The first two continued to draw senior executives from a wide variety of private and public sectors. The three trial balloons were very well received, to the extent that they will be offered again in 1991, incorporating the improvements learned from the first-time-around initiatives.

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 has completed a textbook on applied econometrics entitled *The Practice of Econometrics: Classic and Contemporary*. His other research focussed on constructing a price index for personal computers that adjusted for quality change over time, modeling and measuring the effects of deregulation and mergers on costs and productivity growth in U.S. railroad firms, assessing the interdependent markup and pricing behavior of the Big Three auto-makers in the United States, and examining the conduct of statistical inference in econometric models that are nonlinear in the parameters and variables.

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 primary research is on the analysis of energy and resource projects, using methods of modern corporate finance. The focus is on evaluation methods for projects facing volatile output prices, complex tax-induced non-proportionalities in cash flows, and operating flexibility.

Professor Robert S. Pindyck continued his research on irreversible investment decisions, focusing on capacity choice under price and cost uncertainty. He also studied commodity markets, testing the present value model of rational commodity pricing, and developing and testing models of commodity storage.

Professor Nancy L. Rose continues her work on the determinants and effects of government regulatory policies. Her current research investigates airline pricing structures, with a focus on the effects of competition and entry on price dispersion. She also is studying airline service quality provision.

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 Garth Saloner continued his theoretical research on standardization and compatibility. He broadened the scope of this line of research to include case studies and a detailed empirical analysis of the adoption of automated teller machines. He wrote a case study of a recent merger in the paper industry, and launched several new projects on the nature of the firm.

Professor Richard L. Schmalensee has been 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.

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 of the joint behavior of asset prices and business cycle variables in which investors have preferences over consumption that are temporally dependent. The investigation also involves the development of a statistical methodology that accounts for the presence of approximation error in the model solution. Over the past year he has developed a PhD course in empirical finance as well as two half courses in PhD-level macroeconomics.

Professor 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 been on leave this year as a Batterymarch Fellow at the Sloan School. His research has shown that stock market prices do not follow random walks, and that these departures are the result of important lead/lag relations among groups of stocks. Such lead/lag relations contribute to the profitability of contrarian trading strategies. He has also completed studies on the behavior of stock prices within the day, on spurious rejections of financial asset pricing models that arise from datasnooping, and on detecting long-term memory in economic time series.

Institute Professor Franco Modigliani has continued his work on macroeconomic policy and performance. He has studied the problems of unemployment and economic stagnation in Europe, and the potential for cooperation and coordination in the design and conduct of macroeconomic policies. He has devoted a major portion of his research efforts to an understanding of the reasons for the worldwide decline in saving rate between the '60's and the present.

Professor Stewart C. Myers continued work on signaling models of accrual accounting and the role of discretionary accounting choices in conveying information to investors. He is also developing a new organizational theory 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.

Professor John E. Parsons has continued his work on long-term supply contracts, focusing on the international natural gas market. He has also done further work on incentive schemes, and on capital financing arrangement.

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 Jean-Luc Vila currently studies 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.

Accounting. Professor Ravi Bhushan has worked in the area of the role of information in financial markets. He has developed a model of analyst coverage viewing the number of analysts following a firm as a proxy for the total equilibrium expenditure on information collection about the firm. He has also been developing a model of liquidity and informed trading that accounts for interdependence among the trading costs in various asset markets.

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 investors interpret managers' financial decisions, such as dividend policy changes, equity offerings, and stock splits.

Professor Uri Ronnen has been studying the relationship between regulation market condition, and the quality of auditing. He has shown that, contrary to common beliefs, minimum quality standards have no anti-competitive effects. He has also shown that the disparity between the quality of various CPA firms can be attributed to the effects of the Security Acts of 1933-34 on auditors' incentives.

Management Science

The Management Science Area encompasses marketing, operations management, information technology, probability and statistics, and operations research. Several important research topics are being undertaken including the modeling of multistage production/inventory systems, models to aid the management of software development and measures of software productivity, risk management in financial credit services, and the integration of marketing and engineering.

Members of all the subgroups have continued to play various roles in the LFM Program. In particular, Professor Steve Graves has replaced Professor Tom Magnanti (on leave) as co-director of the program.

Operations Management. Professor Gabriel Bitran has continued his work on the network-of-queues model, particularly as it applies in the context of manufacturing systems. He has also begun work on modeling the performance of service operations, and started to develop a methodology for assessing the status of quality in services. Professor Bitran was selected to be editor for *Management Science*.

Professor Graves' new work focuses on understanding the value of production flexibility in various forms, and includes the supervision of LFM projects at Kodak, Boeing and General Motors.

Professor Charles Fine continues his research on quality management, modeling of manufacturing costs and performance, and evaluation of manufacturing technology. He is developing new frameworks and models for computer integrated manufacturing, for assessing flexibility, and for managing learning and improvement processes.

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 Wein was awarded a Presidential Young Investigator Award.

Professor Karl 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 MIT's Artificial Intelligence Laboratory, and was awarded an NSF grant from the Strategic Manufacturing Initiative (joint with G. Chryssolouris and S. Graves).

Professor Steven Eppinger's research activities consist of projects aimed at improving product design procedures and manufacturing process control techniques. He also conducts research projects within MIT's Laboratory for Manufacturing and Productivity, with funding from NSF, DEC and General Motors.

Professor Anantaram Balakrishnan's research includes the development of models and algorithms for network design with application to the planning of capacity expansion for local telecommunications networks. He has begun work on system design and planning issues in manufacturing, in the context of electronic assembly and for process planning.

Information Technologies (formerly Management Information Systems). 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.

Professor Richard Wang is working on the issue of "where is the data from?" in CIS by means of a polygen model he has developed for tagging data sources in heterogeneous database systems. In addition, he has worked with Professor Madnick and Dr. Yang Lee on modeling the cooperating and competing forces in organizations through the concept of territorial entity.

Professor John Henderson has continued to study the value of strategic information systems planning, measurement of the effectiveness of information systems' activities, and management of the design environment.

Professor Chris Kemerer has developed models to aid the management of software development and maintenance, and is developing and testing measures of software productivity. Professor Kemerer acted as guest editor for a special issue of *Decision Support Systems*.

Dr. Jeffrey Meldman continues to track developments in the legal protection of information, particularly proprietary rights in software and personal rights of privacy.

Professor Wanda Orlikowski's research concerns the relationship between information technology and applied organizations. She has continued her research into the automation of systems development work, and began two studies: one examining the role of electronic communication media in coordinating work, the other into the restructuring of organizations through information technology.

Dr. John Rockart continues his work on critical success factors 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.

Operations Research and Statistics. Using statistical and probabilistic methods, Professor Arnold Barnett has studied subjects that inform public policy, particularly in the arenas of aviation safety and criminal justice.

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.

Professor Peter Kempthorne has examined the influence of outlier data in regression modeling in finance. He has also continued collaboration with Professor Roy Welsch on risk management in financial credit services.

In addition, Professor 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, probabilistic 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 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.

Marketing. Professor John D.C. Little has continued to combine data, analysis, and theory to help managers understand better the effects of marketing variables. The real contribution of this research is to provide natural language output that managers can use and accept. In other research Professor Little has been developing measures for distribution and merchandising that provide realistic summaries of market conditions.

Professor Glen Urban has been working to develop an information accelerator to better understand how consumers use information to evaluate new products. In particular, Professor Urban has developed a personal-computer-based system which simulates a showroom-shopping experience for a new automobile.

Professor John Hauser has been focusing on the integrating of marketing and engineering. Also, Professor Hauser has been working with Professors Urban and Wernerfelt to understand how consumers form consideration sets. (A consideration set is the set of products that consumers consider seriously when making a purchase decision. In many product categories consumers consider only a small fraction of the available products.) Professor Hauser is editor-in-chief of *Marketing Science*.

In addition to his work in consideration sets, Professor Birger Wernerfelt has been working to understand the relationships among economic theory, marketing science, and corporate strategy. In particular, he has been examining how a firm can understand and utilize its strengths when entering new markets, developing new products, or changing its marketing variables such as advertising and promotion.

Continuing in the quantitative tradition Professor Wujin Chu has been using mathematical modeling to understand how firms communicate with one another by the manner in which they set their strategic variables.

Professor France Leclerc has begun a research program to study consumer decision making. In one series of experiments she is using a new theory of consumer behavior in which product attributes with higher perceptual salience are overweighted by the consumer. Another series of experiments attempt to understand the psychological experience of waiting by studying the mediating role of various factors on consumers' reactions to delay.

Professor William Qualls augments the behavioral perspective by studying the behavior of buying centers in industrial marketing decision.

Behavioral and Policy Sciences

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, human resources and industrial relations, technology and innovation, organization studies, international management, 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.

In May, 1990 the faculty in our area held a conference with approximately 30 invited industry representatives on the topic of "Systemic Change in Organizations." The purpose was to explore the implications of our research for the broad topic of organizational change. A book that contains the papers and the dialogue from the conference is now being edited and will be published by Oxford University Press.

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 chief executive officers (CEOs) play in using information technologies to change organizational practices. Professor Schein was also honored this year by being elected to be a Fellow of the Academy of Management.

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.

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. He has followed 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. He is now in the process of using his National Science Foundation grant to extend this work to other sites and has begun working with several companies in our LFM Program. His work provides new theoretical 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 highly acclaimed new book titled *Tales of the Field: On Writing Ethnography* by editing a special issue spring, 1990 of the *Journal of Contemporary Ethnography* devoted to analysis of different ways to present ethnographic research findings. 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 has begun a major study of work, career, and family issues using ten year follow-up data from Sloan School graduates. In addition, she prepared a paper for our organizational change volume that outlines the need for managers to bring family considerations into decisions about organizational design and human resource policies. This 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 discussions of this issue. Professor Bailyn is carrying her work into practice as a member of several national panels and study committees and as part of the MIT Family/Work Committee.

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, 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.

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.

One critical set of human resource policy questions has to do with the relationships between new technology and the labor force. As part of their work for the Management in the 1990s Program, Professors Lisa Lynch and Paul Osterman published a paper that analyzes the employment effects of information technology in a large telephone company. They found that the effects of technology are not unidirectional—some jobs are lost, some of the new ones created are of lower skill and some are of higher skill.

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.

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. 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.

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 ombudspersons' offices, Professor Rowe published several papers on the role of ombudspersons, 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 is now following up the publication of its first policy paper with a national forum that will explore the alternative models for the future of worker representation in the US. Professors McKersie and Kochan are drafting the background paper for those discussions. Currently, Professor McKersie and several colleagues are extending this research into the railroad, paper, and other industries in anticipation of preparing a new book on this topic. This work builds on and will update his classic contribution on the behavioral theory of negotiations.

In addition, this year Professor McKersie serves as President of the Industrial Relations Research Association, the major professional association in this field. Professor McKersie was also appointed the Edgar Schell Sloan Fellows Professor of Management this year in honor of both his scholarly achievements and his service as teacher and chair of the Sloan Fellows Program.

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.

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 for a study of safety practices in the petrochemical industry. In addition Professor Kochan and Visiting Professor Michael Useem are editing the book based on the papers and dialogue from the area's conference on organizational change.

Senior Lecturer Donald Ephlin joined 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 LFM Program and has begun work on a book tracing the changes the evolving role of union leadership in the process of transforming American industry.

Management of Technological Innovation (MOT). 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 MOT 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. This year Professor Allen also began work on the effects of computer aided design (CAD) on product development time. His tentative conclusions are 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.

During this past year Professor Eric von Hippel continued to study the interdependence between production tasks and the innovation process. 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 began work on a study of 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. His current work focuses on the mini-mills in the steel industry and in the oil exploration industry.

Professor Michael Rappa is studying how revolutionary breakthroughs in technologies occur and are absorbed (or rejected) within organizations. Professor Rappa published an initial paper on this subject and is conducting further experiments in various industrial settings to extend his data base and further test his model. During this year he conducted a major survey designed to collect data on how the technical literature within scientific networks affects the process of technological development.

Professor Edward Roberts completed his book 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 under the title "Entrepreneurs and High Technology."

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. She has also begun a study of the role of collaboration among users, vendors, and process developers in electronics firms in the development of new production technologies. Professor Tyre was also a very active participant in the LFM 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.

Strategy and Policy. While most all of our research addresses issues of strategic concern to organizations, our strategy and policy 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 strategic 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. This program is a five-year, \$5 million corporate-sponsored program involving a large

number of our faculty. Its purpose is to study the roles played by information technologies in the strategies and processes of organizations today and in the future. During this final year of the program Professor Scott Morton supervised the conceptualizing and drafting of the chapters for the book that will summarize the major research findings of this program. Professor Scott Morton is also working on another book that draws out the broader implications of this research for management.

Professor Michael Cusumano is studying the 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 analysis promises to provoke considerable thought and discussion among academics, managers and public policy representatives (such as Defense Department officials interested in software standards). A major book summarizing this work will be published later this year by Oxford University Press under the title "Japan's Software Factories: A Challenge to U.S. Management."

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 also began a long term project designed to assess the value of using information technology in organizations. IBM is funding this project.

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. Professor Henderson was also a very active participant in the LFM Program this past year.

International Management. We have identified the challenges of managing in a global, highly competitive environment as a key dimension of our school's new mission statement. As such our international management group plays a key role in helping to coordinate our efforts to address these issues.

Professor Donald Lessard's work 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 conducting 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. In addition, Professor Lessard's edited volume, *Managing the Globalization of Business*, was published this year. This book is a product of a conference held with STOA, a business school in Italy that the Sloan School has helped to launch.

Professor Eleanor Westney is an organizational sociologist with special expertise and interest in Japan. While on leave 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.

Professor Richard Locke focuses on the interactions between industrial restructuring and industrial relations in Italy. He has written several papers on this topic from his dissertation and is now in the final stages of turning this work into a book manuscript.

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 an article on this subject and completed a major report that summarized much of his current work on this topic for the National Institute for Dispute Resolution, the leading foundation supporting the development of alternative dispute resolution techniques. Professor Nyhart is also at work on a study of negotiating joint ventures with firms in Eastern Europe.

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. Senior Lecturer 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 this year and has been widely acclaimed in reviews by organizational theorists, technology experts, and business historians.

Affirmative Action

The school continues along its strategic objectives in this area in creating opportunities to increase the presence of women and under-represented minorities in the faculty ranks, working with women faculty toward the goal of a tenured position within the school, and maintaining or potentially increasing under-represented minorities in our varied programs and activities.

We hope to accomplish this by:

- 1) actively working with current minority visiting faculty to determine the feasibility of moving to a tenure track position. Look for similar future appointments whenever feasible;
- 2) working closely with our current women faculty to achieve the intellectual goals necessary for promotion and tenure;
- 3) continuing our progress in increasing the enrollment of women and under-represented minorities in our various programs, which not only increases the future pool of potential candidates for our Doctoral Program and hence our faculty pool, but also creates an inviting environment to new candidates.

It is widely acknowledged that the pool of underrepresented minority candidates is very small, relative to the number of faculty positions available. Although we have not been successful in bringing individuals directly into the tenure track positions, we have recruited two blacks, providing them a special opportunity for advancement to the faculty ranks. One of them was hired as a visiting associate professor. The second individual is a black female with a PhD in Applied Mathematics. She was given a two-year appointment as a lecturer in order to gain an understanding of how operations research methodology could be applied in a business environment and for her to develop an appropriate research agenda.

This strategy of extending visiting/lecturer appointments is clearly the more realistic approach to attain our objectives.

We are pleased with our recent success in granting tenure to one of our women faculty and are very optimistic that further progress will be made.

Attracting underrepresented minorities into our doctoral program, which increases the pool of potential faculty, has been difficult. However, we have been successful in bringing underrepresented minorities into our other degree-granting programs, and have provided school fellowship support when central and external sources have decreased, to maintain the progress in recruiting underrepresented candidates.

In the area of fund raising, we are able to utilize unrestricted funds to support twelve students. The total support to minorities and women from unrestricted and restricted sources totaled \$150,324., which provided support to 13 students.

We have continued to make efforts to attract women and minorities into our academic programs. This past year, our classes included the following women/minority presence: Sloan Fellows - 12.5% (7 of 56); Senior Executives - 19% (6 of 32); Management of Technology - 12.5% (5 of 40); Doctoral Program - 24% (22 of 93); Masters Program - 35.5% (87 of 245).

We continue to improve our outreach to qualified applicants. Two efforts by the Sloan Fellows Program are noteworthy: an appointment to Special Alumni Committee to reach out to minority candidates and two minorities to the Board of Governors of the Society of Sloan Fellows. In the Master's Program, a task force has been established to research how we can effectively recruit minorities and women.

EXTERNAL RELATIONS**Resource Development**

A summary of the Sloan School's FY90 income indicates an excellent year for development efforts. The school raised a total of \$19,490,168 in cash and pledges in FY90. Of this amount, cash gifts and pledge payments totaled \$9,596,618, of which \$4,788,577 were pledge payments on prior commitments. Once again this total was the highest cash revenue in the history of the school's development efforts (a 52% increase over cash received in FY89). In addition, new pledges totaled \$9,893,550 (more than double the FY89 total). Of the cash gifts and pledge payments, we received \$4,450,821 in expendable revenue and \$5,145,797 in endowment in FY90, an increase of 86% and 31% respectively over FY89 totals.

<u>Current</u>	<u>FY89 Total</u>	<u>FY90 Total</u>
Unrestricted	387,250	443,776
Fellowships	91,034	189,539
Chairs	-	-
Restricted Research	631,400	2,842,035
Restricted-Research System Dynamics	541,886*	904,746
Research Patrons	-	-
Other	<u>745,496</u>	<u>70,725</u>
Total Current	\$2,397,066	\$4,450,821
<u>Endowment</u>		
Unrestricted	47,181	56,292
Fellowships	27,036	2,864,978
Chairs	3,834,559	2,217,877
Restricted Research	-	-
Research Patrons	-	-
Other	<u>8,850</u>	<u>6,650</u>
Total Endowment	\$3,917,626	\$5,145,797
Grand Total	\$6,314,692	\$9,596,618

*In the previous year's President's Report this figure was listed separate from current revenue.

Notable among the gifts was \$2,000,000 from Nanyang Technological Institute in Singapore representing the first 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 East Asia Management Studies program. We anticipate that the East Asia initiative will generate additional significant revenue in FY91 as the Sloan School attempts to globalize its curriculum/research activities.

We received a significant gift of \$2,313,621, the proceeds from the estate of Louis E. and Theresa Seley. This gift will help provide scholarships and fellowships for Sloan School students and is the product of the hard work of former Dean Abe Siegel. Three other significant gifts were a gift from Ron Kurtz 54MG for \$450,656 to create the Kurtz doctoral fellowship fund in management of technology and gifts/pledges of \$220,000 each from John R. Bemis 44'AR and James L. Waters 46WC for the Systems Dynamics Program at the Sloan School. These gifts, partly related to the retirement activities of Professor Jay Forrester, helped to boost the systems dynamics group revenue to \$904,560 compared to \$541,886 in FY89. Finally, Jay Spencer Standish 45MG pledged \$1,500,000 for a full professorship in management. Payments from this pledge will begin in FY91.

As we move towards the last two years of MIT's Capital Campaign, we anticipate that major gifts from alumni will be on the decline. Accordingly, we have developed a funding vehicle for medium ranged donor prospects, the Research Patrons program, which will be marketed to prospects having the capacity to fund \$50,000 or more over 5 years. This program allows us to package a combined expendable/endowment request which will support both current research and add to the base of research support for future years.

Along with our efforts to find new and creative ways of involving our alumni in cultivating and fundraising activities, we anticipate that the school's globalization initiatives will continue to bring in new revenue, some of which will come from our international alumni.

Staff Changes, Promotions & Visitors

During the 1989-90 year, ten faculty were appointed to chairs at the Sloan School. Gabriel R. Bitran was appointed to the Nippon Telegraph and Telephone Professorship, a new chair that was established through a gift from NTT in 1989. Professor Bitran has been a member of the operations management faculty since 1978; his research interests encompass operations in both manufacturing and service industries; he also holds an LFM Professorship. Michael A. Cusumano was appointed the Mitsubishi Career Development Assistant Professor of Management, a chair formerly held by Professor Westney. Professor Cusumano works in the area of corporate strategy and technology management in Japan, and wrote a major book on Japan's industrial development, *The Japanese Automobile Industry: Technology and Management at Nissan and Toyota* (1985). Chris F. Kemerer was appointed as the Douglas Drane Career Development Assistant Professor of Management Science, a chair formerly held by Professor Malone. Professor Kemerer's research interests include management and measurement issues in information systems and software engineering. Professor Thomas A. Kochan was appointed the George Maverick Bunker Professor of Management, a chair formerly held by Professor Little. As a member of the Industrial and Labor Relations faculty, Professor Kochan has focused his research and teaching interests in modeling and evaluating innovations in human resources and industrial relations practices. Two faculty were appointed to the IRI Career Development Professorships as a result of a gift from IRI (STOA) in 1989: Richard M. Locke, who has conducted research in Italy and this country in the automobile and textile industries and in new technologies and industrial relations in both Western Europe and the US; and Lisa M. Lynch whose research focuses on the areas of unemployment, labor economics, applied econometrics and comparative industrial relations. Another new chair was established in the area of information technology, resulting from a gift from our alumnus, John Norris Maguire. The chair was granted to Professor Stuart E. Madnick, who has performed scholarly research in the key strategic, organizational, and technology issues on connectivity of large-scale information systems. The Jay W. Forrester chair was also newly established this year as a result of funds from the Thomas Watson Foundation. The first appointee to the chair is Professor Michael S. Scott Morton who has concentrated his teaching and research on the impact of information technology on the strategic operations open to a firm, development of interactive computer-based systems to support managerial decision making, and development of planning systems that allow organizations to adopt to changes in the external environment.

Professor Karl Ulrich was appointed the Ford International Assistant Professor of Management, a chair formerly held by Professor Froot. Professor Ulrich works in the areas of computation and design, including tools for conceptual design, simulation and modelling, product design and design for manufacturing.

Professor N. Venkatraman was appointed to the Richard L. Leghorn (1939) Management of Technology Innovation Career Development Professorship established through a gift from our alumnus, Richard S. Leghorn. Professor Venkatraman has been studying the impact that information technology has in firm-level strategy; in particular, "electronic integration"—how managers use information technology to compare their firms' competitive positions in the marketplace, to change the nature of the relationships with suppliers, customers, and other significant partners.

Six faculty were promoted to full professor: John S. Carroll, who joined the faculty in 1983. Professor Carroll received a PhD degree in organization studies from Harvard University. This research deals with the way people understand and make judgements about their social world, and with the way these judgements translate into actions or decisions. Randall Davis received his PhD degree from Stanford University in 1976. He joined the faculty at Sloan in 1983 and has studied role-based systems, where he helped create the fundamental concepts and architecture now widely used for such systems. He has also explored the area of model-based reasoning. Chi-fu Huang earned a doctorate degree from Stanford University in 1983. He has been on the faculty since 1982, focusing his attention to a number of areas of financial theory, including dynamic general equilibrium theory, intertemporal utility theory, aviation theory, and the theory of optimal consumption and portfolio decisions. Thomas W. Malone received a PhD in psychology from Stanford University in 1980. He came to the Sloan School in 1983 and has been directed at a number of topics related to human problem solving and has emphasized a wide range of theoretical and methodological approaches. Julio Rotemberg received a PhD in 1981. He has been on the Sloan faculty since 1980, turning his studies to the central problems of macro and international econometrics regarding the intensity of business fluctuations, the volatility of exchange rates, and globally deleterious effects of shocks like energy price increases. Thomas M. Stoker received his PhD in economics from Harvard University in 1979. He has been on the Sloan faculty

since that time, concentrating on the development of empirical models of demand behavior which attempts to capture individual and aggregate level.

Two faculty were granted tenure: Associate Professor John Sterman received a doctoral degree from the school in 1982. He joined the System Dynamics faculty in 1981, and has studied managerial decision making in complex organizations using experiments and simulation models. By coupling behavioral decision theory at the macro level with aggregate organizational behavior, he is broadening the domain of managerial decision theory. Dorothy Eleanor Westney received a PhD from Princeton University in 1978. She has been a member of the International Management Group since 1982, and is best described as a discipline-based researcher who has produced high-quality, influential studies of organizational emulation in Japan, and who is applying the same rich framework with similar success to issues of international management.

Three faculty were promoted to associate professor this year: Charles H. Fine joined the faculty in 1983, after completing a PhD in business administration from Stanford University. His principal research focus has been to apply operations research methodology and economic modeling in areas that are amenable to analysis and play an important role in determining the manufacturing competitiveness of firms and nations. Lisa M. Lynch earned a doctorate from the London School of Economics in 1983. She became a part of the industrial relations faculty in 1985, studying neoclassical labor economics, focused on models which described behavior of individuals and the institutional labor economics to provide an understanding of the broader context in which individuals operate. Nancy L. Rose joined the economics group at the school after receiving a doctoral degree from MIT in 1985. Her main fields of study include the economics of regulation, government management of risk, and technology policy.

Faculty new to the Sloan School in 1989-90 included: John C. Heaton who holds a joint appointment at the Sloan School and with the Economics Department as an assistant professor, earned a doctorate in economics from the University of Chicago in 1989; France Leclerc, Assistant Professor of Marketing, with a PhD in 1989 from the Johnson Graduate School of Management; Uri Ronnen, Assistant Professor of Accounting, who obtained a PhD degree from Stanford University in 1989; Jean-luc Vila, Assistant Professor of Finance, who received a PhD from Princeton University in 1987; and Birger Wernerfelt, Associate Professor of Marketing, who obtained a doctorate of business administration from Harvard University in 1977.

The school also invited a number of visiting faculty: Paul Asquith, Visiting Associate Professor, from Harvard University Graduate School of Business Administration; David P. Brown, Visiting Assistant Professor of Finance, from Indiana University School of Business; Amihud Dotan, Visiting Associate Professor from Tel Aviv University; Arthur Lewbel, Visiting Assistant Professor, from Brandeis University; Christopher Lovelock, Visiting Senior Lecturer from Lovelock and Associates; Jeffrey A. Miron, Visiting Associate Professor, from the National Bureau of Economic Research; James E. Owers, Visiting Professor, from Harvard University; Leslie E. Papke, Visiting Assistant Professor, from Boston University School of Management; Michael Useem, Visiting Professor, from Boston University; J. Nicholas Ziegler, Visiting Assistant Professor, from Harvard University.

Changes in academic appointments included J.J. Donovan from Associate Professor with tenure to Adjunct Professor; Jay W. Forrester to Germeshausen Professor of Management Emeritus and Senior Lecturer; Steven H. Star to Senior Lecturer and Editor-in-Chief of the *Sloan Management Review*; Y. Richard Wang from Visiting Assistant Professor to Assistant Professor.

Six faculty were on sabbatical leave: Professors Ernst Berndt, John C. Cox, Gordon M. Kaufman, Thomas L. Magnanti, Garth Saloner, Roy E. Welsch. Other faculty on leave included Kenneth A. Froot, Nancy A. Rose, Richard Schmalensee, D. Eleanor Westney.

Administrative promotions included Frances C. Cummings, Assistant to the Publisher; Sarah W. Cliffe, Managing Editor, *Sloan Management Review*; Paula Cronin, Publisher; Kimberly Miner, Circulation Manager, *Sloan Management Review*.

New administrative staff included Brent M. Carlton, Financial Analyst; Ellen Quaadgras, Systems Analyst; and Xiazhang Zhou, Associate Director of the East Asia Program.

Three faculty departed this year: John Parsons, Assistant Professor; John Henderson, Associate Professor; Garth Saloner, Associate Professor. Administrative staff departures included Jean Anderson, Administrative Assistant; Sandra Anthony, Program Coordinator; and Carol Peterson, Circulation Manager.

LESTER C. THUROW

SCHOOL OF SCIENCE

The School of Science contains five academic departments and the directors of six laboratories or centers also report to the Dean of Science. Reports from department heads and directors of laboratories and centers are included as separate items in this yearly summary.

During the past year the Cell Culture Center ceased operations. This center was organized in 1974 (with support from the National Science Foundation and more recently from the National Institutes of Health) as a service organization to provide cultured animal cells to biological scientists at MIT and other institutions in the Northeast. Don Giard served with competence as director of the center for its entire lifetime.

EDUCATION

Last year I reported on several projects that were to be initiated in the 1989-1990 academic year in connection with undergraduate education in the School of Science. In this report I review the actions that were taken and evaluate the results of those actions.

During the past year an experimental subject in introductory physics was offered in the fall term to a limited number of self-selected first-year undergraduate students. This subject was designed to include limited laboratory experience (in the form of "take-home" experiments) as well as some material not included in introductory physics subjects at MIT in the past. Professors Anthony French and John King, both of the Physics Department, collaborated in teaching this experimental subject. The subject was well-received by the students. They particularly appreciated and enjoyed the emphasis on the presentation of physics from the experimental point of view. Plans have been made to offer this experimental subject again during the 1990-1991 academic year.

Another experiment that was initiated in the past year is a new subject that combined the teaching of Biology, Chemistry and Materials Science in a two-semester sequence to a selected group of first-year undergraduate students. This experimental subject was organized to assess the feasibility of presenting introductory material in these three disciplines in an integrated fashion and in such a way that the subject would satisfy the General Institute Requirements for Chemistry and Biology (it is anticipated that Biology will be added in the near future as a General Institute Science Requirement). This subject was organized and taught by Professors Silbey (from the Chemistry Department), Latanision (from the Department of Materials Science and Engineering), and Ingram (from the Biology Department). Although we view this as a two-year experiment (the subject will be repeated in the 1990-1991 academic year), the interim reports give reason to be optimistic about the feasibility of this ambitious project.

Finally, a permanent committee has been established to maintain oversight of the Institute science requirements. This committee contains faculty members from the Schools of Science, Engineering, and Humanities and Social Science as well as student representation. The chairman of the committee during the past year was Professor Hartley Rogers of the Mathematics Department. A major activity of this committee during the year has been the monitoring and evaluation of the experimental subject in chemistry-biology-materials science.

AFFIRMATIVE ACTION

The hiring of women and minorities as faculty members continues to be a high priority project in the School of Science, although I am sorry to report that we have not made as much progress in the past several years as we would like. The Biology Department has recently made offers to three women as assistant professors and is currently waiting to hear from them. The Chemistry and Biology Departments have offered an assistant professorship to a Black scientist and are waiting to hear from him.

The School of Science is continuing efforts to stimulate minority students to enroll in graduate programs by co-sponsoring (with the Graduate Office and the Whitaker College) the Minority Summer Science Research Program. This summer there are 19 minority students (selected from 140 applicants) in residence on the campus engaged in research activities under the supervision of faculty members. This is the fifth consecutive year of this program. The success of the program is indicated by the fact that more than 90% of the previous participants are now enrolled in graduate schools or medical schools. More details about this program can be found in my report for last year.

STAFF CHANGES

On July 1, 1989 Richard Hill succeeded Charlene Placido as Assistant Dean for Financial Administration in the School of Science. Mr. Hill moved to this office from the Budget Office of MIT.

Prof. Gordon Pettengill stepped down as Director of the Center for Space Research on June 30, 1990, and was succeeded as Director by Professor Claude Canizares, who had been serving as Deputy Director since July 1, 1989. We offer our thanks to Professor Pettengill for six years of devoted service as Director and we welcome with enthusiasm Professor Canizares as the new Director.

ACADEMIC PROGRAMS

There were 714 undergraduates in the School of Science during the past academic year, a decrease (-5.43%) from the previous year. The number of minority students at the undergraduate level changed as follows:

Blacks	Increased from 15 to 25 (67% increase)
Hispanics	Increased from 20 to 24 (20% increase)
Native Americans	Increased from 0 to 1
Asian Americans	Decreased from 141 to 139 (-1.42%)

The female undergraduate population increased by 1%. Twenty-two percent of the Institute's upperclass undergraduates were enrolled in the School of Science.

Graduate enrollments in science decreased from 1,082 in the 1988-89 academic year to 1,068 (-1.3%) in the 1989-90 academic year. 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 15 to 11 (27% decrease)
Hispanics	Increased from 9 to 12 (33% increase)
Native Americans	Increased from 1 to 2 (100% increase)
Asian Americans	Increased from 24 to 28 (17% increase)

The number of female graduate students remained constant at 259.

There were 262 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'90 volume of research was approximately 99 million. This represents a 10 percent increase over the FY'89 total of 90 million.

HONORS and AWARDS

This past year Professor Vernon Young, professor of nutritional biochemistry in the School of Science, was named a winner of the prestigious Rank Prize in Nutrition; he was also elected to the National Academy of Sciences as well as being elected President of the American Institute of Nutrition..

GENE M. BROWN

Department of Biology

INTRODUCTION

The Biology Department currently has 60 faculty members of whom 15 are located in the Whitehead Institute, 11 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. Four of the faculty are Nobel laureates, 18 are members of the National Academy of Sciences and 5 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 is currently in an advanced state of design and is expected to be occupied late in 1992.

EDUCATIONAL ACTIVITIES

Undergraduate Program

In the past year, the maximum number of undergraduates registered as Biology majors was 284. Of these, 72 received the degree of Bachelor of Sciences in Biology: 52 in the regular Course VII Program, 20 in the VII-A Program.

Fifty-eight percent of our majors are women and 6.8% are underrepresented minorities.

Several changes have been made in our undergraduate program during the past year.

A year ago, the Committee on the Undergraduate Program proposed that a Biology requirement be added to the MIT Core Curriculum. The first pilot subject toward this goal was developed by Professors Vernon Ingram (Biology), Robert Silbey (Chemistry), and Ronald Latanision (Materials Science and Engineering). This two semester subject, SP01 Chemistry, Materials Science and Biology, and SP02 Chemistry, Materials Science and Biology, was taught for the first time this year to a trial group of 100 freshmen and received good reviews from the students. The overall goal of the subject is to provide a unified and coherent progression from Chemistry to Biology. The Biology component of SP01/SP02 is intended to provide the conceptual basis for all other biology subjects and focuses on cell biology, genetics and recombinant DNA techniques, embryo development and the human nervous system, and a discussion of the social context of modern molecular biology. We also reorganized 7.01 General Biology as another prototype for a general Institute requirement; our goal is to give students sufficient grounding in the general principles of biochemistry and modern genetics such that they will be able to build on this knowledge whenever they encounter biological problems in their own lives and future careers. In addition, the new version of 7.01 stresses the development of analytical skills necessary to apply knowledge of fundamental biological precepts to the analysis of modern issues in biotechnology, health, medicine, and the environment.

The highly successful Project Laboratories continue to be a cardinal feature of our undergraduate training, aided in part by support from a grant by the Howard Hughes Medical Institute.

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, 1989 to June 30, 1990, 19 Ph.D. degrees and five Master's degrees were awarded in the Department; three 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 1989-1990 was 175, with another 20 in the Joint Program. The entering class in 1989, including three in the Joint Program, was 37. The class arriving in September, 1990 will number 36, including three WHOI students.

Thirty-nine percent of our graduate students are women and 0.005% are underrepresented minorities. The Graduate Program is supported by several Training Grants from NIH, by small amounts of industrial and foundation support and from research grants.

Two new subjects were added to our graduate curriculum during the past year, 7.64 Advanced Cell Structure and Function, and 7.65J Principles of Neuroscience.

RESEARCH

The research activities of the Department are in the areas of molecular biology, biochemistry, genetics, cell and developmental biology, immunology, neurobiology, microbiology, and virology. Research projects are described in the annual publication *Biology Research Summaries* available in the Biology Headquarters Office (56-511).

Research volume for FY 90 was \$26 million, 88.5% from federal government grants. This research volume represents a 5 percent increase over FY 89 despite the current difficult research funding environment. In addition to the faculty and students, 232 Postdoctoral Fellows and Associates perform research in laboratories of Department faculty.

PERSONNEL

Professor Brent Cochran was promoted to Associate Professor effective July 1, 1990, and Professor David Raulet was promoted to Associate Professor with tenure effective July 1, 1990.

Dr. Christopher Kaiser has accepted a position as Assistant Professor of Biology and plans to join the Department during the Fall 1990 term. 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.

Dr. Eric Lander accepted a joint appointment as Associate Professor with tenure in the Department and Member, Whitehead Institute for Biomedical Research effective October 1, 1989. Dr. Lander, who received the A.B. in 1978 from Princeton University and the D. Phil. in 1981 from Oxford University, both in mathematics, had been a Whitehead Fellow and Research Affiliate in the Department of Biology since 1984. His primary research interests are in the areas of mathematical biology and human genetics. He will add strength to our research in human genetics and mathematical expertise to the analysis of data generated by modern molecular biology.

Dr. Carl Pabo has accepted a position as Full Professor effective July 1, 1990. Dr. Pabo received the B.S. in Molecular Biophysics and Biochemistry in 1974 from Yale College and the Ph.D. in Biochemistry and Molecular Biology from Harvard University in 1980. He is currently an Associate Professor in the Department of Molecular Biology and Genetics of the Johns Hopkins Medical School, and an Investigator, Howard Hughes Medical Institute, Johns Hopkins. Dr. Pabo is a crystallographer, a biophysical chemist, and a molecular biologist who is internationally known for his work on protein-nucleic acid interactions. His broad range of interests will complement those of several of our faculty and will add significant strength to our research and teaching programs in biochemistry.

Professor JoAnne Stubbe, Ellen Swallow Richards Professor of Chemistry, accepted a joint appointment in Biology effective July 1, 1990. Dr. Stubbe has made significant contributions to our teaching program and to our intellectual life, and we are pleased to welcome her as an official member of the Department.

Professor Boris Magasanik, Jacques Monod Professor of Biology, formally retired from the faculty June 30, 1990. Dr. Magasanik's contributions to the Department during the past 30 years have been many and substantive. He served as Head of the Department from 1967 to 1977, significantly strengthening our teaching and research programs during a period of rapid expansion for the Department. His continued involvement in Department and Institute activities have helped make this a better place for students, faculty, and staff to flourish. Dr. Magasanik will continue his research activities, and will also continue to participate in our teaching program; we are pleased that he has chosen to do so.

The Biology Department is committed to increasing representation of women and minorities among our faculty. We have recently made offers to four junior faculty members, three of whom are women and the fourth Afro-American.

Three faculty members have left the Department this year. We will miss them all but wish them well in their future careers.

Professor David Baltimore left the Department June 30, 1990 to take the position as President of The Rockefeller University in New York.

Professor David Botstein left the Department in January 1990 after a period of leave. He is currently Vice President for Science at Genentech but will become Chairman of the Genetics Department at Stanford effective July 1, 1990.

Professor Barbara Meyer left the Department June 30, 1990 to accept a faculty position at the University of California, Berkeley.

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 Gerald R. Fink was named the second Director of Whitehead Institute, effective July 1, 1990, succeeding Professor David Baltimore.

Professor Leonard Guarente was selected as the Thomas D. & Virginia W. Cabot Career Development Associate Professor of Biology; he is the second member of our faculty to hold this chair.

Professor Richard Hynes was named Head of the Department and Professor Robert Sauer Associate Head on July 1, 1989.

Professors Peter Kim and David Page were awarded the Walter J. Johnson Prize of the Editorial Board of the Journal of Molecular Biology in honor of their contributions to Molecular Biology. Dr. Kim also received a Rita Allen Foundation Award.

Professor Ruth Lehmann received one of 20 David and Lucile Packard Fellowships in Science and Engineering for 1989 to support her research on pattern formation in the fruit fly *Drosophila melanogaster*.

Professors David Page and Hermann Steller have been named Assistant Howard Hughes Medical Institute Investigators.

Professor Paul Schimmel was elected to the National Academy of Sciences.

Professor Frank Solomon won the Graduate Student Council Teaching Award for 1989-90, for the fifth time.

Professor Lisa Steiner was elected Fellow of the American Association for the Advancement of Science for her efforts on behalf of the advancement of science.

Professor Susumu Tonegawa received the Rabbi Shai Shacknai Award from the Hebrew University of Jerusalem, given annually to honor "an outstanding work figure in immunology and cancer research".

RICHARD O. HYNES

Department of Chemistry

The Department of Chemistry remains one of the Nation's leading academic centers in the chemical sciences. Known for its scope and quality, the Department has an education and research program covering all the major areas of chemistry. In the 1989/1990 academic year about 100 post-doctoral associates or fellows, 250 Ph.D. students, 100 undergraduates, 35 faculty, and a staff of 50 were actively engaged in the Department's programs. With about \$14 million in research support the Department executes a large basic research effort of fundamental and practical importance, both for the value of the new knowledge obtained and the value of the educational benefits. In an effort of such breadth and quality it is difficult to single out "the best" research. However, two efforts deserve special attention. First, Professor Richard R. Schrock and his group are developing a new polymerization procedure based on well-defined catalysts for ring opening metathesis polymerization. New polymeric materials with new properties can now be prepared by rational design. Second, Professor Julius Rebek and his group have duplicated a biological process; they have prepared a "self-replicating molecule" [*Journal of the American Chemical Society*, **112**, pp. 1249-1250, (1990)]. These two research activities represent two areas of great excitement, materials chemistry and biological chemistry. Both involve complex systems and both yield to progress in molecular synthesis --- the heart of chemistry. The sections below summarize some of the Department's other activities and highlights for 1989/1990.

ACADEMIC DEVELOPMENTS

The Department has undergone a thorough external review of its undergraduate educational programs, in order to gauge its quality and scope. The Department's Undergraduate Curriculum was reviewed November 28-30, 1989, by a review team of outstanding chemical educators from leading four-year colleges: Professor Michael P. Doyle of Trinity University; Professor Mitsuru Kubota of Harvey Mudd College; Professor Colin F. MacKay of Haverford College; Professor Jerry R. Mohrig of Carleton College and Professor Stewart R. Novick of Wesleyan University. The Review Team met with faculty, graduate teaching assistants, and undergraduates. They attended classes, inspected the laboratories, and met with the Dean of the School of Science, Gene M. Brown, and Dean of the Undergraduate Program, Margaret M. MacVicar. Chemistry fared well with respect to most areas but the team recommended several areas of improvement including (1) the need for an immediate and large infusion of capital for undergraduate laboratory equipment, (2) introduction of laboratory experiences earlier in the program, (3) development of biological chemistry core subjects, (4) more involvement in undergraduate research; (5) high technology (computers, demo facilities, etc.) in more of our classrooms. Importantly, the Review Team concluded that we have an unusually strong commitment to undergraduate education, considering the strength of the graduate education and research program. These recommendations have begun a discussion among faculty, students, and the administration that will lead to an improved undergraduate program in chemistry. Two significant responses are to offer a laboratory component to our first subject in organic chemistry (5.12) in the Fall of 1991 and to acquire a high field, multinuclear NMR for the Undergraduate Labs. Professors Alan Davison and Daniel Kemp are developing the new laboratory subject. The Chemistry Department received an award from the National Science Foundation to support a new, advanced undergraduate laboratory unit in the area of picosecond spectroscopy. In another important undergraduate offering, Professor Robert J. Silbey is participating in a two-year experimental freshman offering which integrates chemistry, materials science, and biology in a two-term subject. The Institute experiment is to be evaluated in 1990/91.

CAMPAIGN FOR THE FUTURE

The Department has been active in connection with the MIT *Campaign for the future*. Several major events took place and will be summarized here.

Establishment of the Edward R. Kane Fund

On October 5, 1989, the Department officially announced that the Edward R. Kane Fund had been established with a gift from Texas Instruments Incorporated on the occasion of Dr. Kane's retirement from the Board of Directors. The Department hosted a luncheon in Dr. Kane's honor, and a number of distinguished guests attended including Mr. Cecil H. Green '23, Founder of Texas Instruments; Mr. Jerry Junkins, Chairman of the Board of Texas Instruments; Provost John M. Deutch; Mr. Jerry McAfee, Chairman of the Department of

Chemistry Visiting Committee and a Member of the MIT Corporation. At MIT Dr. Kane (Ph.D. '43) was a member of the Corporation from 1979-1989. He has been Chairman of the Visiting Committee for Mechanical Engineering and has served on several Visiting Committees including Chemistry. During his tenure on the Chemistry Visiting Committee he was instrumental in securing resources for the renovation of the Undergraduate Laboratories. From 1974 to 1988 he was a member of the Corporation Development Committee. Income from the Kane Fund is intended to enhance the quality of chemistry research and education at MIT.

Chemistry Department/ Alumni/ae Telethon

The Department in conjunction with the Association of Alumni and Alumnae held the Chemistry Graduate Alumni Telethon on October 11. Professor Mark S. Wrighton, joined by seven graduate students and two alumni raised \$17,195 from 157 donors in three hours. An additional 73 alumni made unspecified pledges.

Establishment of the CIBA-GEIGY Professorship

Dr. Paul E. Gray, President, MIT, announced on October 19, 1989, that CIBA-GEIGY Limited had established a \$3 million fund for the establishment of the CIBA-GEIGY Professorship and Research Endowment in the Department of Chemistry. Dr. Gray said the gift marks the first time an endowment at MIT will support both a professor's salary and the research in the professor's laboratory. The announcement of the gift was made in Cambridge by Dr. François L'Eplattenier, Member of the Executive Committee of CIBA-GEIGY Limited, at a special MIT symposium, "Molecules to Materials: Chemistry's Next Frontier", held to celebrate the announcement. CIBA-GEIGY Limited is engaged primarily in the development, manufacturing and marketing of a wide variety of pharmaceuticals, special-purpose chemicals, electronic equipment, lasers and vision care products. CIBA-GEIGY has more than 88,000 employees in 60 countries worldwide, including 20,000 in North America. The symposium featured presentations by Professor George M. Whitesides of Harvard University; Professor David M. Walba of the University of Colorado and Professor Mark S. Wrighton, Department Head. Following the presentations, Dr. Gray announced that Provost John M. Deutch had named Professor Mark S. Wrighton, Head of the Department, to be the first holder of the Professorship. Professor Wrighton stated that this philanthropic gift from CIBA-GEIGY, one of the world's outstanding scientific companies, demonstrates how appropriate it is for the private sector to have this kind of long-term vision to support teaching and fundamental scientific research at MIT; this endowment represents a unique opportunity to encourage path-breaking research and assist in the development of generations of creative scientists.

Establishment of the Paul and Marcia Cook Fund for Innovation in Chemistry

The establishment of the Paul and Marcia Cook Fund for Innovation in Chemistry was the highlight of a Department Open House on April 26, 1990. Vice President and Treasurer Glenn P. Strehle and Department Head Mark S. Wrighton announced the establishment of the Cook Fund at the Open House marking the occasion. Mr. Paul M. Cook '47, founder and Chairman of the Board of Raychem Corporation, presented a memorable lecture "The Role of Chemistry in Entrepreneurship". Mr. Cook is a Life Member of the Corporation as well as a member of our Department's Visiting Committee. He served as its chairman for 17 years, from 1971 to 1988. Mr. Cook's lecture was timed to coincide with the Spring national meeting of the American Chemical Society and was followed by a departmental open house for visiting alumni and guests. Following the Department's Open House Mr. and Mrs. Cook were honored at a gala dinner. Addressing the faculty after dinner, Mr. Cook expressed his deep feelings of affection and respect for the Department, and challenged the faculty to continue to take risks, be innovative and use the Cook Fund to pursue their ideas, encourage their intellectual curiosity, and sustain their emotional drive.

OUTREACH PROGRAMS

The High School and Elementary School Chemistry Outreach Program executed by our graduate and undergraduate students continues to be an unqualified success. 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. This program has received significant financial support --- \$25,000 each --- from MIT Chemistry Department Alumnus, Class of 1942, Mr. James K. Littwitz and from the Corporate Contributions Committee of Houghton Mifflin Company. Sustained effort of both of our outreach programs will, however, require additional resources. In an related vein, the Department has participated in an Institute-wide activity, led by Professor

Ronald M. Latanision, to acquaint New England area high school science teachers with MIT's activities. Approximately 50 teachers spent a week on campus in an intense, schedule of five days of activities in science and engineering. In conjunction with the Houghton Mifflin Company and Professor Mark S. Wrighton, the Department hosted the "Frontiers in Freshman Chemistry Workshop". This workshop was intended to enhance instruction in introductory college chemistry by identifying cutting edge chemistry research that illustrates some of the principles of chemistry. Invited participants were all involved in chemical education and interacted with four leading academic chemists in a day-long session highlighting new chemistry that can be introduced to freshmen. 45 freshman subject instructors from colleges and universities across the U.S. attended. The Department actively participates in programs to improve our educational programs, encourage better understanding of chemistry and increase the level of interest in the chemical sciences among the pre-college students. We hope that our chemistry colleagues in government, industry and academia will continue to support our efforts.

The Departmental newsletter *Chemformation* continues its weekly publication featuring many topics including students, faculty, a Department and Institute Seminar Calendar, articles of academic and scientific interest, as well as a monthly feature, *Chemical Sciences Industry Forum*, which highlights departmental research. The employment opportunities section continues to expand thanks to the participation of our academic and industrial colleagues. *Chemformation* distributes weekly 500 copies Institute-wide and approximately 150 nationally and internationally. In addition it is now distributed electronically as part of a new service offered by the MIT Libraries known as AlcheMITs.

HONORS AND AWARDS

The Department is proud to note that two faculty awards deserve special mention. First, **Professor George H. Büchi**, Camille and Henry Dreyfus Professor, was selected to receive the 1990/91 James R. Killian Faculty Achievement Award - the Institute's highest faculty achievement award. Established in 1971, the Killian Award recognizes "extraordinary professional accomplishments by full-time members of the MIT faculty". Professor Büchi is one of the world's leading figures in the area of organic chemistry.

Second, **Professor Stephen L. Buchwald**, Firmenich Associate Professor, received the MIT Harold E. Edgerton Junior Faculty Achievement Award. This award was announced at the April meeting of the Institute faculty and is the capstone of Professor Buchwald's term as a non-tenured faculty member. Chemistry faculty receiving both the Edgerton and Killian Awards symbolizes the quality of our faculty contributions in research, teaching and service.

Professor Stephen L. Buchwald also received the 1989 Innovation Recognition Award from Union Carbide Corporation's Chemicals and Plastics Group.

Professor Sylvia T. Ceyer presented one of the two Langmuir Lectures at the Miami ACS Meeting, September 12, 1989. The Langmuir Lectures are the major plenary lectures of the Colloid and Surface Division and play an important role in the ACS effort to educate membership regarding general aspects of surface and colloid chemistry.

Professor Alan Davison was selected to receive an Honorary Fellowship from the University College of Swansea in the United Kingdom. Professor Davison was awarded the Herbert M. Staffer Award for Outstanding Laboratory Paper 1990 by the Association of University Radiologists. Dr. Davison also celebrated 25 years of service with MIT.

Professor John M. Essigmann was awarded an Outstanding Investigator Award from the National Institutes of Health.

Professor Robert W. Field was named co-recipient of the American Chemical Society's 1990 Nobel Laureate Signature Award for Graduate Education in Chemistry. This honor is awarded annually for the best Chemistry Ph.D. thesis, authored by Dr. Yongqin Chen under the joint supervision of Professor Field and former colleague Professor James L. Kinsey.

Professor Robert G. Griffin was also selected by the National Institute of General Medical Sciences to receive a MERIT (Method to Extend Research in Time) award. The MERIT award is a mechanism established by the National Institutes of Health to provide long term support for investigators of proven competence and productivity.

Professor Daniel S. Kemp celebrated 25 years of service with MIT.

Professor Peter T. Lansbury was selected as a 1990 Presidential Young Investigator.

Professor Stephen J. Lippard was the second annual Aquanatics Lecturer at the University of California at Davis. Dr. Lippard also delivered the 1990 Donald G. Davis Memorial Lecture at the University of New Orleans and presented the thirty-fifth annual Clifford Phillips Lecture Series at the University of Pittsburgh. He also received a MERIT award for his studies on the "Chemistry and Biology of Platinum Anti-Cancer Drugs".

Professor Philip W. Phillips was awarded a Whitaker Health Science Fund Award.

Prof. Keith A. Nelson was named the first Edward R. Kane Scholar.

Professor Richard R. Schrock was appointed Frederick G. Keyes Professor of Chemistry on July 1, 1989. Dr. Schrock was also the speaker for the Edward H. Boomer Lecture Series at the University of Alberta, Edmonton.

Professor JoAnne Stubbe, the Department's Ellen Swallow Richards Professor of Chemistry, has accepted a joint appointment with the Department of Biology. In addition, Dr. Stubbe was selected by the MIT Graduate Council as the recipient of the Graduate Student Teaching Award for the Department of Chemistry.

Institute Professor John S. Waugh tied for Third Prize with Pennsylvania State University in the 1989 IBM 3090 Supercomputing Competition for Outstanding Work in Large Scale Computer Analysis and Modeling.

Professor Mark S. Wrighton was the guest and speaker for the first Annual Alexander M. Cruickshank Endowed Lectureship at the University of Rhode Island. In addition, other invited lectures include the Ernest H. Swift Lecturer at the California Institute of Technology; the Sunner Lecturer at the University of Lund, Sweden; First Xerox Lecturer at the University of Alberta, Alberta, Canada and Distinguished Lecturer at the University of Louisville.

Professor Hans-Conrad zur Loye was selected as a recipient of a Camille and Henry Dreyfus Newly Appointed Faculty Award.

The National Science Foundation selected 17 young scientists to be 1990 Postdoctoral Research Fellows in Chemistry. Three of these scientists are conducting their research within our Department: **Dr. Chad A. Mirkin, Dr. Vincent M. Rotello, and Dr. Patrick J. Walsh.**

PERSONNEL

Professors Sylvia T. Ceyer and John M. Essigmann have been promoted from Associate Professor to Professor.

Professor Stephen L. Buchwald has been promoted to Associate Professor with tenure.

Professors Philip W. Phillips and Douglas C. Youvan have been promoted from Assistant Professor to Associate Professor.

Dr. Robert G. Griffin joined the Department of Chemistry as Professor of Chemistry. Professor Griffin is one of the world's leading figures in the area of magnetic resonance techniques applied to the determination of the structure of biological molecules. Dr. Griffin is also Associate Director of the Francis Bitter National Magnet Laboratory.

Professor Mario J. Molina joined MIT with a primary faculty appointment in Earth, Atmospheric and Planetary Sciences and holds a joint appointment in the Department of Chemistry. Dr. Molina was formerly with the Jet Propulsion Laboratory at the California Institute of Technology. He is an experimental chemist with a record of achievement in stratospheric chemistry.

Dr. Les Whitaker joined the Department as the new Undergraduate Lab Director. Dr. Whitaker received his degrees from the University of Denver and the University of the Pacific, Stockton, CA. He previously directed the Undergraduate Laboratory at the University of Southern California, a position he held for 10 years.

Dr. Cynthia D. LuBien (Ph.D. '82) was appointed the Chemistry Department's chief liaison for corporate relations. Dr. LuBien, who is also a senior officer of the Institute's Industrial Liaison Program, divides her time between the Department and the ILP. She is serving as the Department's chief contact to the ILP as well as assuming administrative responsibilities for the Department's Chemical Sciences Industry Forum.

Professor Gregory Petsko and Dr. Dagmar Ringe have departed MIT to assume faculty positions at Brandeis University.

Mrs. Vera Spanos retired after 14 years in the Department of Chemistry. Mrs. Spanos worked with many physical chemists including Professors Ceyer, Deutch, Kinsey, Oppenheim, Phillips and Silbey. A primary responsibility of staff and administration is to provide support for faculty and students which will help them achieve their scholarly agenda. We at MIT are very privileged to have dedicated support staff.

The Department has greatly expanded its recruitment and placement support to graduate students and postdoctorals. This ongoing effort seeks to enlarge our listing of industrial recruiters, as well as strengthen our ties with Chemistry Postdoctorals no longer at the Institute.

MINORITIES AND WOMEN IN CHEMISTRY

The Department is aggressively attempting to increase the involvement of underrepresented minorities and women in the chemical sciences. In one new effort, together with several other faculty and MIT colleagues, Professor Mark Wrighton is currently developing a program of interaction with historically black colleges and universities which is intended to increase the pool of Black-American students entering graduate programs in the chemical sciences. Naturally, a local objective is to improve the under represented minorities in our program, but this will not be enough. The Department feels we must raise interest and consciousness of opportunities in chemistry for more than those already decided on their careers. This effort will be a long term one, but one of great importance for American academia, industry, and government laboratories. Drawing on the rich human resources available will make certain a stronger chemistry enterprise.

The Women in Chemistry group have just completed a successful third year. The monthly lecture luncheons featuring industrial and academic speakers were well attended. Their ongoing purpose continues to be the encouragement of women within the Chemistry Department to know and interact with one another; create a supportive environment where concerns can be addressed and dealt with; to spread general information on various subjects dealing with life at MIT concerning both men and women, and to provide a network for women at MIT to come in contact with other women in chemistry.

DISTINGUISHED VISITORS

The Chemistry Department was privileged to host several distinguished scientists in endowed lectureships during the past academic year. Professor Benjamin Widom of Cornell University was the Arthur D. Little Lecturer in Physical Chemistry in November 1989; December 1989, brought Professor John E. Bercaw of the California Institute of Technology as the Arthur D. Little Lecturer in Inorganic Chemistry. The T.Y. Shen Lecturer was Professor Daniel E. Koshland of the University of California, who visited in February 1990; the second George H. Büchi Lecturer in Organic Chemistry was Professor Gilbert Stork of Columbia University, who visited in April 1990. Capping the distinguished lectureship program was Nobelist Jean-Marie Lehn of the Université Louis Pasteur as the Karl Pfister Lecturer. Each of these distinguished lecturers spent several days in the Department lecturing, visiting with faculty, and interacting with students.

STUDENT ACTIVITIES

In the Fall of 1989 the Department admitted 61 students to the graduate program. The Department awarded 37 B.S. degrees, 5 M.S. degrees and 47 Ph.D. degrees this year.

Many graduate students received fellowships and awards for the academic year 1989/1990: Donald F. Storey was awarded the Mary A. Terry Fellowship for Graduate Studies; John L. Kane was awarded a Flying Tigers Scholarship; Brian R. Dixon was appointed the first recipient of the Squibb Fellowship; James A. Hill was presented the Phillip L. Levins Memorial Prize by the Northeastern Section of the American Chemical Society; Ted Ashburn was awarded two postgraduate scholarships, one from the National Collegiate Athletic Association and the other from the National Football Foundation and Hall of Fame, Inc.; Todd Anderson a Howard Hughes Fellowship; Andrew Rapp one of the first Joint Services Electronics Fellows, is the recipient of a three year fellowship from the Joint Services Electronics Program; Orin Tempkin received the first Merck Chemical Manufacturing Division Fellowship; Michael Wolfe has been awarded a predoctoral fellowship from the Natural Sciences and Engineering Research Council of Canada. Several of the Department's first-year graduate students were recently awarded National Science Foundation Fellowships for September 1990: Christopher C. Cummings, Stephanie A.B. Solina and Kingsley L. Taft.

The Department awarded several chemistry undergraduates with the following awards: C. Hunter Baker, Erica W. Kuo and Robert Rich received Alpha Chi Sigma Awards for Achievement in Research, Scholarship and Service to the Department; Jung Ku and Erica C. Kuo were awarded the Merck Index Award for Outstanding Scholarship; the Department of Chemistry Undergraduate Research Award was presented to Jessica A. Cook; Erica W. Kuo was honored with the Participant in the Du Pont Summer Research Program Award; C. Hunter Baker received the American Institute of Chemists Foundation Student Award. In addition Ms. Erica Kuo was initiated into the Xi Chapter of Phi Beta Kappa. Three undergraduate members of the Department were recipients of National Science Foundation Fellowships for September 1990: Seth N. Brown, Erica W. Kuo and Michael J. Nohaile.

On November 1, the MIT Chemist's Club, in conjunction with the MIT Alumni/ae Association sponsored its annual industry panel discussion. The purpose is to try to assist the graduate students and postdocs to become more familiar with responsibilities of a scientific job in the industrial sector. Representatives from industry were Dr. Louis Kaminski, Du Pont; Dr. Ed Chandross, AT&T Bell Laboratories; Dr. George T. Wildman, Merck Chemical Manufacturing Division; Dr. David Williams, Eastman Kodak and Dr. Daniel Keohane of the Raychem Corporation. Dr. Charles Kolb of Aerodyne Research Incorporated served as moderator.

On a lighter note and proving once again that MIT students excel in more than just science and engineering, a team consisting of the Department's graduate students and postdocs outscored twelve teams to take first prize in the third annual New England Chemistry Department Softball Tournament.

MARK S. WRIGHTON

Department of Earth, Atmospheric, and Planetary Sciences

In 1990 the Department of Earth, Atmospheric and Planetary Sciences (EAPS), Course XII, celebrated its one-hundredth anniversary as a degree-granting program at MIT. This occasion was marked by a week of activities in early June, which included the Technology Day program, an EAPS open house, a special History of Earth Sciences Symposium, and a technical conference honoring the distinguished career of Bill Brace, who retired in 1988 as Department Head. EAPS begins its second century with strengths in a wide range of disciplines that concern scientific questions critical to a global society.

FACULTY AND RESEARCH STAFF

Changes in the faculty of EAPS include the appointment of three new professors. Professor Mario Molina is an experimental chemist who was the principal author on the 1974 paper (with S. Rowland) which put forward the original chlorofluorocarbon-ozone depletion theory; more recently, he proposed and demonstrated experimentally a new reaction which enables stratospheric ClO in polar regions to catalytically destroy ozone, thus elucidating the basic chemistry of the Antarctic Ozone Hole. Professor Hager is a geodynamicist, best known for his work on mantle convection and the interpretation of the long-wavelength geoid. He is also leading a major field program to measure the deformation of coastal California by space-geodetic techniques. Professor Thomas Herring is a space geodesist, who has been involved in the development of Very Long Baseline Interferometry (VLBI) to measure continental baselines with subcentimeter precision. He and his colleagues documented the first direct observations of plate motions on a human time scale, and they have observed significant deviations from the predicted retrograde annual nutation, which they have interpreted as arising from an anomalous ellipticity of the core-mantle boundary.

On July 1, 1990, Edward Boyle was promoted to Professor, Kip Hodges and Brian Evans to Associate Professor with tenure, and Earle Williams and Dan Rothman to untenured Associate Professor. Professor Gene Simmons retired in October, 1989, and Assistant Professor Jason Phipps Morgan left MIT for the Scripps Institution of Oceanography in June, 1990.

Honors

Honors awarded to EAPS personnel include the election of Senior Research Scientist Peter Molnar to the National Academy of Sciences and Professor Emeritus Edward Lorenz as a Foreign Member of the Royal Society of London. Professor Lorenz was also given an honorary membership in the American Meteorological Society, and he received an honorary D.Sc. from Rutgers University. Professor Leigh Royden received the Donath Medal of the Geological Society of America. Professors Richard Binzel and John Grotzinger were selected as Presidential Young Investigators. Professor Burns received a Guggenheim Fellowship Award from the John Simon Guggenheim Memorial Fund in recognition of his research on poorly crystalline materials formed as oxidation products of iron silicate and sulfide minerals during chemical weathering on terrestrial planets. The 1989 "Annual Award for Service Through Chemistry" was presented to Professor Mario J. Molina by the American Chemical Society, recognizing his pioneering and continuing atmospheric chemistry studies to elucidate the interactions of chlorofluorocarbons with ozone in the stratosphere.

EDUCATION

The Department's revised undergraduate curriculum will be implemented in the next academic year. The plan, developed by the EAPS Undergraduate Committee, calls for the institution of a series of core curriculum courses, one each in Geology and Geochemistry, Geophysics, Planetary Science, and Meteorology and Physical Oceanography, and a new course in continuum mechanics. Undergraduate majors are required to take three. In addition, the subjects that follow in a student's individual program of electives have been more explicitly defined.

The Department has also been active in setting up new courses and revamping older offerings to better inform non-majors about the excitement throughout the range of disciplines covered by the Department. An example is 12.111 Chaos and Complexity, initiated this academic year by Professor Dan Rothman. This Science Distribution subject introduces undergraduates to nonlinear dynamical systems, providing access to a new set of mathematical tools and physical methods that are becoming important across a diverse spectrum of applications. The Department continues to develop its graduate and undergraduate offerings in global environmental studies, which are especially popular with non-majors. One increasingly popular course is 12.23 Environmental Chemistry: Human Impact, taught by Professors Ed Boyle and Ron Prinn; it examines the chemistry and physics of anthropogenic global change, including the problems of enhanced greenhouse warming due to CO₂ and other emissions, stratospheric ozone depletion by CFCs, and acid rain.

CENTER FOR GLOBAL CHANGE SCIENCE

The EAPS Department, in cooperation with the Department of Civil Engineering and the Department of Chemistry, has set up a new Center for Global Change Science to organize research and educational activities related to global climate change and other large-scale,

long-term environmental effects. The Center's research initiatives focus on long-standing scientific problems whose solution is necessary for the accurate prediction of anthropogenic global change. The long-term goal is to utilize theory and observations to understand the fundamental mechanisms controlling the global environment. The initial objectives involve a sustained program of basic scientific research concentrated on five fundamental processes in the global climate machine: convection and cloud formation, oceanic circulation and ocean-atmosphere coupling, land-surface hydrology and hydrology-vegetation coupling, biogeochemistry of the greenhouse gases, and upper atmosphere chemistry and circulation. Professor Ron Prinn of EAPS has been appointed as Director, and Professor Rafael Bras of Civil Engineering as Deputy Director.

CURRENT RESEARCH

Geology/Geochemistry

Projects are underway by Professor John Grotzinger and his students include the examination of the elastic strength of the Proterozoic continental lithosphere, the driving mechanisms of 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.

With his students, Professor Southard has continued work on one of the fundamental problems of sedimentary dynamics: the interaction between the transported sediment and the depositional interface, and its bearing on the texture of the deposited sediment. One striking and counterintuitive result that demonstrates the surprises that may be lying in wait: the stronger the flow, the finer the deposit, other things being equal.

Professor Fred Frey and colleagues have focussed on geochemical studies of basalt from drill cores of the Ninetyeast Ridge, a 5,000 km chain of submerged volcanoes comparable to the Emperor-Hawaiian Ridges. Their results show that for more than 100 m.y. isotopically anomalous components have been involved in creating the Indian Ocean seafloor. One of these components is also seen in the Kerguelen Island hotspot, and it has the isotopic characteristics of ancient sediment.

Professor Tim Grove and his students have been using the methods of experimental petrology to study the melting processes in the upper mantle that accompany crustal extension at mid-ocean ridges. A large amount of chemical differentiation occurs during this decompression melting process and it is the dominant mechanism by which mass is transferred from the earth's mantle to produce crust. They have developed a procedure to predict quantitatively the compositions and temperatures of melts in equilibrium with the mineral assemblage left in the mantle when melt is extracted over the range of relevant pressures. They apply this technique to interpret the significance of the compositional variations observed in mid-ocean ridge basaltic magmas and to infer the chemical characteristics of the mantle source and the extent of melting that occurred.

Professor Roger Burns and his graduate students Duncan Fisher and D'Arcy Straub have been developing spectral mineralogy techniques to characterize nanophase products formed in different geochemical environments. Mossbauer spectra measured at 4.2K have enabled x-ray amorphous ferric oxides to be identified in precipitates from acid mine drainage, in brines believed to occur in some regions on Mars, and in aerial oxidation products of iron silicate and sulfide minerals formed during extrusion of basalts onto planetary surfaces. Collaborations with Valerie Wood and Dr. Teresa Bowers have delineated stability fields of zeolites, as well as their cation exchange reactions with cesium and strontium, in experiments simulating exposure to leakages that could result when high level radioactive waste is buried in zeolitic tuffs in Nevada.

The major focus of the research of Kip Hodges and his students continues to be the thermal evolution of mountain belts. Studies in collisional orogens such as the Himalayas and continental arc regions like the Mesozoic Sevier orogen of western North America indicate that mechanical decoupling within the continental lithosphere leads to the development of both extensional and compressional zones at different structural levels within a convergent setting. Work by Hodges' and co-workers on the development of Tertiary extensional and strike-slip basins in the Death Valley region of California indicates a straightforward link between the development of local structures and facies variations in the basin fill. All of these projects require high-precision dating of minerals. The EAPS geochronological facilities will be greatly enhanced this next year by the construction of a joint MIT-Harvard rare gas mass spectrometry lab that will be directed by Hodges.

Professors Burchfiel and Royden have completed a one-month study of late Cenozoic and active faulting in Bulgaria. This work is a continuation of ongoing studies by Professor Royden and her students on the processes of collision, subduction and extension in the

eastern Mediterranean region. The Bulgarian work clearly shows major active extension in the eastern Mediterranean reaches north to central Bulgaria and that considerably greater extension occurs in southern Bulgaria than had previously been recognized.

Dr. Teresa Bowers has spent the past year assessing theoretical stability relationships between tellurium and arsenic-bearing minerals, theoretical constraints on gold deposition, and initiated a combined solution chemistry and petrographic study of the El Indio gold deposit (Chile) together with Raymond Jannas (Harvard). In addition, stable isotope modeling of H₂O-CO₂ fluids has shown that oxygen isotopes mix nonideally in coexisting fluid phases.

Geophysics

Professor Thomas Herring has been investigating the geophysical applications of space geodetic techniques. During the past year he has completed a major analysis of over nine years of very long baseline interferometry (VLBI) data and, along with colleagues from the Harvard-Smithsonian Center for Astrophysics and the University of Madras, India, has determined from this analysis an accurate model for the forced motions of the Earth rotation axis in space. He and graduate student Danan Dong have also determined, for the first time, amplitudes and phases of diurnal and semidiurnal variations in the rotation rate of the Earth. These results have been interpreted as being largely due to tidally induced ocean currents.

Dr. Robert King, Professor Bradford Hager, Professor Thomas Jordan, their students, and colleagues at several California universities, are using space geodesy to measure crustal deformation in central and southern California. By comparing modern GPS measurements with historical surveys, they find 5 - 15 mm/yr N-S convergence in an E-W belt extending from the Santa Maria Basin through the Santa Barbara Channel, to the Ventura Basin. The accuracy of the velocities determined using GPS observations repeated over a span of several years is now comparable to that using historical observations spanning a century.

Dr. Robert Reilinger has been using space geodetic observations to study present-day deformation of the Earth's crust in a number of tectonically active areas including the Eastern Mediterranean region, Southern California/Northern Mexico, and the Rocky Mountains.

Professor Hager and his students are conducting numerical experiments on the MIT Cray-2, using finite element models to address several problems in mantle dynamics. These experiments have shed light on the dynamics of subduction, including penetration of subducted slabs into the lower mantle, on the generation of mantle heterogeneity, and on the stability of the subcontinental lithosphere (tectosphere).

Professor Marcia McNutt completed a sabbatical year at Lamont-Doherty Geological Observatory of Columbia University in New York under the sponsorship of the National Science Foundation's "Visiting Professorships for Women" program. While at Lamont, she continued research on the Cretaceous volcanism of the northwest Pacific, using multichannel seismic and other geophysical data to demonstrate that the anomalously shallow seafloor is not caused by crustal thickening, but rather by a massive late-Cretaceous thermal event.

Professor Daniel Rothman has obtained new results in the fluid dynamics and statistical mechanics of immiscible fluid mixtures. These findings, obtained by computer simulations of discrete hydrodynamics, increase basic understanding of phenomena ranging from the complex flow of fluids in porous media to the interaction of growth and hydrodynamics in phase separation. He and graduate student Andrew Gunstensen are developing a new computational approach to these problems that will greatly facilitate investigations of three-dimensional multiphase flows.

Professor Brian Evans and his coworkers are investigating the kinetics of solid state reactions in metamorphic rocks; the experiments indicate a coupling between grain boundary migration rates and the introduction of major elements into solid solution, and imply that many physical properties may be affected by metamorphic reactions. In a second project Evans and colleagues are investigating the effect of melts and solid second phases on the failure modes of rocks. The transition from brittle failure to plastic flow, in particular, is thought to be of great importance in many tectonic and geophysical problems.

Professor Sean Solomon, with his colleagues and students, has been applying the techniques of seismic tomography to investigate the nature of magmatism and its relation to the tectonic and morphological segmentation along mid-ocean ridges. Along-axis variations in seismic structure and microearthquake mechanisms on a slow-spreading ridge segment support the hypothesis that the inner-floor along-axis bathymetric high marks the locus of most recent crustal magmatism and most vigorous current rates of cooling. The first three-dimensional seismic images of the axis of the faster spreading East Pacific Rise display a segmentation of the axial low-velocity zone that correlates spatially with along-axis segmentation of seafloor morphology; these results suggest that segmentation at the 10-km scale is controlled by magma injection processes.

Professor M. Nafi Toksöz, along with graduate student B. Oral, has been working on tectonic deformations in Turkey, Iran, and the Caucasus caused by the convergence of the Arabian Plate against Eurasia. Many damaging earthquakes, such as those in 1983 in Turkey, 1988 in Armenia, and 1990 in northwest Iran, have occurred on faults activated by the motions of smaller crustal blocks squeezed between the Arabian and Eurasian lithospheric plates. They have been combining finite element modeling with geophysical

and geological data to determine the pattern of deformations and regions of high strain accumulation with potential for major earthquakes.

Dr. Arthur Cheng, in cooperation with graduate student X.M. Tang, has developed a theory for Stoneley wave propagation and scattering in a borehole with a horizontal fracture. This allows them to relate the flow properties of the fracture with the observed properties of the Stoneley wave. The theory has been confirmed with model experiments in the laboratory. This study has applications in the waste disposal, geothermal, as well as petroleum industry areas.

Using a global network of ultra-long-period seismometers, Professor Jordan and Postdoctoral Research Associate Gregory Beroza have discovered a new type of teleseismic earthquake. These ruptures are large enough to excite the Earth's low-frequency free oscillations, but they propagate so slowly that they do not produce a visible train of high-frequency waves. Professor Jordan and his colleagues have been able to show that such "quiet earthquakes" may precede and initiate some ordinary large earthquakes, which has implications regarding strategies for short-term earthquake prediction.

Planetary Science

Professor Richard Binzel is analyzing photometric data obtained during the once-per-century series of mutual occultations and transits ("eclipses") between Pluto and its satellite, Charon. This analysis reveals a bright south polar cap on Pluto, which is interpreted as being due to a fresh (< 1 million year old) deposit of methane ice. The albedo asymmetry between Pluto's north and south polar regions suggests that there is a long term variation involved in Pluto's seasons, in addition to short term seasonal variations induced by its eccentric 248 year orbit around the sun. This longer term variation is most likely related to the orbit's 4 million year precession in the longitude of perihelion. At the current epoch, Pluto's south pole is in shadow as the planet recedes from perihelion causing preferential condensation and deposition of methane on that pole.

Professor Elliot and graduate student Leslie Young have been performing a new analysis of stellar occultations by Charon, with the goal of setting an upper limit on an atmosphere for this remote body. They find that Charon may well have a tenuous atmosphere of as yet undetermined composition, but further observations are needed to resolve the issue. In spite of recent revelation of optical difficulties with the Hubble Space Telescope, Professor Elliot is hopeful that most of his group's planned investigations of the atmospheres and rings of the outer planets can still be accomplished.

Professor Jack Wisdom has modelled the shape oscillations of the Great Dark Spot in the atmosphere of Neptune. The models suggest that there is widespread deterministic chaotic advection in the atmosphere of Neptune. The models also provide a strong constraint on the Rossby radius of deformation.

Professor Gordon H. Pettengill continues his heavy involvement as Principal Investigator of the radar investigation group of the Magellan Radar Mapping mission to Venus, which is underway towards a rendezvous with that planet on August 10, 1990. This mission is designated to image the entire surface of Venus by radar at a resolution approaching 100 m. Using data from an ancillary radar altimeter on board the orbiter, he will also supervise the preparation of global maps of the topography and surface electrical properties using facilities at the MIT Center for Space Research. Together with Professor 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 producing an extremely high resolution map of the topography of that planet.

Professor Counselman developed a new satellite-based method of monitoring crustal displacement for geophysical research and related applications such as earthquake warning. Using Global Positioning System satellites he obtained precision better than 2 parts in 10^8 (<2mm over 100 km) in single-day measurements. Another, related concept he is pursuing involves putting little radio transmitters, called "GeoBeacons," on the ground throughout an area to be monitored. The transmitted signals are relayed by satellites to a central station. GeoBeacons are simple, low power devices similar to existing search-and-rescue beacons by transmitting at much higher frequencies. The repeater satellites are of the "MICROSAT" class (each a 20-cm cube weighing about 10kg). Only at the central station is a high-gain antenna or non-trivial electronics required.

Oceanography

Professor Carl Wunsch and his group are working towards global scale modelling of the ocean circulation and its fluctuations, and their climate implications. This ambitious goal involves a complex amalgam of many different data types: satellite altimetry, gravity, meteorological forcing, hydrography, and chemical tracers both steady and transient. The combinations are made through mathematical techniques borrowed from control methods combined with conventional oceanographic dynamical models.

Professor Glenn Flierl and his group are exploring the interaction between strongly nonlinear eddies, currents, and Rossby waves. Using simple models, they have discovered general characteristics of meanders of a strong jet and determined how these meanders grow and detach to form eddies. Models of the biological effects show that there should be variations in the distributions of the trophic

levels along the meanders. These models are being compared to field data from the SYNOP and BIOSYNOP programs. Other studies underway include the flow over steep topography and the loss of energy from strong eddies by radiation of Rossby waves.

Professor Paola Malanotte-Rizzoli and her students have continued the studies on the assimilation of different data types into models of the ocean circulation. The main focus has been on the assimilation into a model of the Gulf Stream system of data sets collected at localized clusters of moorings during SYNOP. The results are very encouraging; they show that the assimilation of these localized data points is quite effective in reproducing processes occurring in regions void of data, such as meander steepening and bending of the Gulf Stream jet. As a second research topic, she has extended, together with Dr. Keith Haines, her theory for long-lived, coherent anomalies of atmospheric split flows (atmospheric blocking) to explain the opposite sign coherent anomalies of atmospheric intense jet flows.

Professor Edward Boyle has discovered a serious apparent discrepancy between tracers for the chemical status of Antarctic deepwaters during the last glacial maximum. This discrepancy appears between the carbon isotope and cadmium content of the shells of bottom-dwelling organisms. However, he has proposed that this discrepancy may be accounted for by the unusual carbon isotopic composition of Antarctic plankton. Together with graduate student Yair Rosenthal, he has begun investigation of a new technique for reconstruction of the salinity distribution in ancient ocean.

Professor John Edmond participated in an ALVIN expedition to the Mid-Atlantic Ridge, getting excellent samples of the hydrothermal fluids and "black smoke". We have been analyzing the latter by XRF using the very intense source at the Brookhaven accelerator. In collaboration with Drs. Kurtz (WHOI) and Raisbeck (Orsay), Professor Edmond has successfully determined exposure ages on terminal moraines in the Taylor Dry Valleys region of Antarctica and get agreement between the three cosmic ray produced isotopes, He-3, Be-10 and A1-26 over the time period 20,000 to 2 m.y.

Meteorology

Have global ocean temperatures changed significantly in the past century? To find out Professor Reginald Newell and his colleagues, working with a group at the British Meteorological Office, have produced an Atlas based on 60 million ships' reports collected between 1856 and 1989. For the past decade, a relatively warm period, there was good correspondence between sea temperature changes and air temperatures changes measured by satellite, probably because they are both related to El Niño. From 1950 to 1980 sea temperatures were very stable. At the turn of the century there was a sharp drop in temperature, possibly related to enhanced volcanic activity.

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, which release active chlorine in the stratosphere.

Professor Ron Prinn is studying the global atmospheric chemistry of compounds such as dichlorotrifluoroethane, proposed as replacements for the current chlorofluorocarbons. Using a three-dimensional global model he and his colleague A. Golombek have determined that the atmospheric lifetime of dichlorotrifluoroethane is only 1.5 years and that most (88%) of its destruction occurs in the troposphere rather than in the ozone layer. As a result, for equal rates of emission by mass into the atmosphere, dichlorotrifluoroethane will inject about 14 times less destructive chlorine into the stratosphere than the chlorofluorocarbon it is intended to replace.

Professor Earle Williams and his colleagues in the Weather Radar Laboratory are examining field observations of deep convection from Darwin, Australia (12°S). Order of magnitude increases in lightning activity are associated with modest (1-2°C) increases in surface wet bulb temperature, a result which can be explained by nonlinear invigoration of ice phase microphysics aloft. Theoretical analysis of laboratory measurements of ice particle charging suggest that sublimating graupel particles charge negatively while graupel particles undergoing vapor deposition charge positively.

Professor Kerry Emanuel has developed a new parametric representation of cumulus convection for use in global weather forecasting and climate simulation models. The representation attempts to more accurately account for the microphysics of water in clouds so that an accurate prediction of water vapor (the most important greenhouse gas) can be made. He also developed a new model of the Hadley circulation and analyzed the results of a field experiment which he had planned and executed the previous year.

Professor Peter Stone has carried out diagnostic studies of the ability of the most sophisticated numerical climate models to calculate dynamical heat transports in the atmosphere. He has found that the models' calculations are not robust, but rather are sensitive to the representation of poorly-understood small-scale processes.

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 explaining why the global response to increasing greenhouse gases have been so small and why the atmospheres of the outer planets are banded. He is also working on optimizing the resolution of both numerical models and observation systems, on understanding how tropical easterly waves organize

precipitation, and on what determines the intensity of the general circulation. His book, *Dynamics in Atmospheric Physics*, has just been published by the Cambridge University Press.

Professor Alan Plumb and graduate student Volkmar Wirth have been investigating the reasons for the seasonal cycle of planetary waves in the southern hemisphere stratosphere; they found that a simple model which can satisfactorily simulate the northern hemisphere waves cannot reproduce the southern hemisphere behavior. In collaboration with Dr. Lorenzo Polvani, he is studying the basic fluid dynamical properties of the stratospheric polar vortex. He is also studying the response of the atmosphere to subtropical heating and the mechanism for the strong quasi-biennial fluctuation of the Antarctic "ozone hole".

Professor Randall Dole is currently involved in several observational and modelling efforts focusing on major low frequency phenomena in the atmosphere. Basic goals of this research include identifying the primary mechanisms responsible for the development and evolution of the low frequency phenomena, and determining the relationships between low frequency circulation anomalies and variations in synoptic scale eddy activity. In addition to this work, Prof. Dole is also engaged in studies on the mechanisms responsible for the genesis of small scale cyclones.

THOMAS H. JORDAN

Department of Mathematics

DEPARTMENTAL STATISTICS

Students

During the academic year 1989-90, there were 165 undergraduates majoring in mathematics, including 47 in the 18C program, Mathematics with Computer Science. The figures of the those graduating were: 61 graduating seniors, including 18 in 18C, and 10 double majors.

There were a total of 120 graduate students in mathematics, all in the PhD program. This year 18 students received their PhD, including 13 this last June.

Faculty

There were 55 faculty members in the Mathematics department, 22 in the Applied Mathematics group, and 33 in the Pure group. This included the following on whole or partial leave:

- Professor Michael Artin (Year)
- Professor Alexander Beilinson (Spring)
- Associate Professor Sy Friedman (Spring)
- Professor Sigurdur Helgason (Spring)
- Professor Kenneth Hoffman (Year) as Executive Director of Mathematical Sciences
Educ. Board of the Natl. Academy of Sciences - Natl. Research Council
- Assistant Professor Ehud Hrushovski (Fall)
- Professor Peter Huber (Spring)
- Professor Steven Kleiman (Spring)
- Professor Willem Malkus (Spring)
- Professor Arthur Mattuck (Spring)
- Professor Franklin Peterson (Fall)
- Assistant Professor Antonio Sanchez-Calle (Year)
- Associate Professor David Shmoys (Year)
- Professor Harold Stark (Spring)
- Professor Daniel Stroock (Spring)

There was one visiting professor this year, Professor Louise Raphael from Howard University.

FACULTY CHANGES

Retirements and Resignations:

Professor Harold Stark chose to resign from MIT this year, accepting a department chair at the University of San Diego.

Associate Professor Nicholas Warner resigned to assume a professor's position at the University of Southern California.

Associate Professor Shmoys and Assistant Professor Sanchez-Calle officially resigned to pursue other positions.

New Appointments

Dr. Sheldon Chang has accepted a position as Assistant Professor of Pure Mathematics; his specialty is differential geometry and partial differential equations.

Dr. James Propp has accepted a position as Assistant Professor of Applied Mathematics; his field is combinatorics and ergodic theory.

To date, five and possibly six distinguished faculty will join us as Visiting Faculty next year, Professors Izrail Gelfand, Ivanovich Manin, and possibly Vladimir Drinfeld from the Soviet Union. Professor Isom Herron from Howard University, Professor Helmut Rieder from West Germany and Associate Professor Leon Van Dommelen from The Florida State University.

Promotions

Associate Professor Sy Friedman was promoted to full Professor. His field is logic and set theory.

Dr. Walter Olbricht, an Instructor in Applied Mathematics, was promoted to Visiting Assistant Professor.

Honors, Prizes and Awards

Professor Bertram Kostant is to receive the Steele Prize from the American Mathematical Society for a seminal paper in Algebra.

Professor Steven Kleiman received an honorary Doctoral of Science degree from Copenhagen University.

Professor James Munkres received an honorary Doctoral of Science degree from Nebraska-Wesleyan University.

Professor Isadore Singer received an honorary degree from the University of Illinois.

Professor Gian-Carlo Rota received an honorary degree from the University of L'Aquila, Italy.

Assistant Professor Ehud Hrushovski was selected as an Alfred P. Sloan Research Fellow to support his research over a 2-year period.

Assistant Professor Ali Nadim shared the Science Council Prize for Excellence in Teaching Undergraduates.

Assistant Professor Steven Strogatz received a five-year Presidential Young Investigator Award from the National Science Foundation to support his research.

Two graduate students, Satish Reddy and Alan Thompson, received Alfred P. Sloan Doctoral Dissertation Fellowships.

Two mathematics seniors, Daniel Klain and Timothy Hsu shared the Jon A. Bucsela Prize in Mathematics for distinguished scholastic achievement, professional promise, and enthusiasm for mathematics.

Nine seniors in mathematics were elected to the national honor society Phi Beta Kappa.

ADMINISTRATION

Professor David Benney has completed his first year as Department Head following the tenure of Professor Mattuck.

Professor Robert MacPherson has succeeded Professor Richard Melrose as Chairman of the Pure Mathematics Committee, the remaining Chairs remain the same. They are:

Professor Daniel Kleitman - Applied Committee
Professor David Jerison - Undergraduate Committee
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.

Various efforts are underway to help the least prepared students. Last year, as planned, Visiting Professor Raphael led a regularly scheduled, guided study-group/tutorial in conjunction with 18.01 Calculus and 18.02 Calculus for students identified early as being in trouble. Students who attended were enthusiastic, but many others stayed away because of the remedial stigma. That workshop will be offered again this year, possibly with a link to Program XL, the seminar study group program in freshman math and physics operated by the Office of Minority Education, which has had a better track record in attracting students. The experimental course 18.01A Calculus aimed at students with no previous calculus experience will be discontinued; students avoided it, again because they perceived it as a second-class option. Instead students will be able to take a diagnostic test on high school mathematics on a voluntary basis. Also, a large random sample of students will be given the test in the first recitation. Students who do poorly in one area or another will be given, but not required to look at, a brief set of notes and exercises prepared by Professor Mattuck. In the process we hope that some students will be brought into closer contact with their recitation instructors.

An honors version of the standard ordinary differential equations course developed by Professor Melrose will become a permanent part of the course offerings next fall. So far it only serves math majors, but several engineering departments have expressed interest.

Project Athena has been used successfully for several years in differential equations. Last year Professor Jerison used Project Athena for the first time in the 1801 one-variable calculus course. Some of the programming had to be done at the last minute by supervisors Dr. Jon Haass, Lecturer in the Mathematics department, and Mr. Edward Moriarty, Project Manager in Electrical Engineering & Computer Science department, without much help from the undergraduates. The Athena environment still proved to be unstable, and there were added difficulties of dealing with first semester students. Next year we still plan to use computer-aided problem sets in calculus of both one and several variables, but we will scale down to groups of at most 50 students instead of 300. For next year only we will be working on a cluster of Macintosh computers not yet integrated into the Athena network.

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 Director of the Research Laboratory of Electronics, and the Plasma Fusion Center.

In 1989-90 the total number of the Faculty was 85. The following members of the Faculty received promotions: to Associate Professor without Tenure, Mehran Kardar, Aneesh Manohar, Steven Stahler, John Tonry; to Professor with Tenure, Robert Redwine. One new Associate Professor without Tenure joined our faculty: Boris Altshuler; one new Assistant Professor also joined: Jacqueline Hewitt. One member of the Faculty retired: Bernard Feld.

Faculty on leaves or sabbaticals during the year included: Professors Eric Cosman, Bernard Feld, Michael Feld, Jeffrey Goldstone, Roman Jackiw, John Joannopoulos, Henry Kendall, June Matthews, Aneesh Manohar, Ralph McNutt, Jean-Pierre Revol, and Peter Wolff.

A number of our faculty received awards during the past year. Professor Katherine Freese received the Presidential Young Investigator Award from The National Science Foundation. Professors Simon Mochrie and Jacqueline Hewitt received Alfred P. Sloan Fellowships. Professor Wit Busza received the 1989 Buechner Prize in recognition of outstanding contributions to the educational program of the department. Professor Alan Guth was appointed the Jerrold Zacharias Professor of Physics, and Professor Marc Kastner was appointed as Donner Professor of Physics. Professor Patrick Lee was named the William and Emma Rogers Professor of Physics effective July 1, 1990. Professor George Bekefi was selected as the recipient of the second Plasma Science and Applications Awards. The Institute's 1990 Wade Award went to Professor Edmund Bertschinger. Professor Alan Guth was elected to the National Academy of Sciences and the American Association for the Advancement of Science. Professor David Litster was elected a fellow of the American Academy of Arts and Sciences. The 1990 Graduate Student Council Department Teaching Award was given to Professor Mehran Kardar. Professor June Matthews was elected Fellow of the American Association for the Advancement of Science.

With regard to student honors, the 1989 Buechner Student Teaching Prize was awarded to Juliana Hsu. Deborah Kuchnir received the 1989 Joel Orloff UROP Award and the 1989 Apker Prize, a national award given by the American Physical Society for excellence in research as an undergraduate. Cynthia R. McIntyre received a Karl Taylor Compton Prize from MIT. The Laya W. Weisner Award was presented to Luisa R. Contreiras and the Association of MIT Alumnae Award was presented to Sima Setayeshgar. Eight students were elected to Phi Beta Kappa: Walid Azzam, David Bitko, Isaac Chuang, Niraj Desai, John Driscoll, Gerard Luk Pay, Ferase Rammo, and Sima Setayeshgar.

Educational Achievements

The Department has continued to maintain a relatively constant 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 210, and the number of graduate students was 281. The number of degrees awarded totaled 68 S.B., 6 S.M., and 34 Ph.D.

CURRENT RESEARCHAstrophysics 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. The recent 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. In galactic astrophysics, researchers are investigating several phenomena involving neutron stars in binary star systems using the GINGA satellite in collaboration with Japanese colleagues and using EXOSAT archives. One major area of study is the phenomenon of quasiperiodic oscillations of accretion disks around neutron stars. Studies of eclipses of the X-ray star by the companion are being used to trace the density structure of the sub-sonic winds in luminous stars. Data from the SAS-3 archive are being used to study the black hole candidate A0620-00 and the soft X-ray background. A long-term program to identify hard X-ray sources from the HEAO-1 all-sky survey has just been completed, yielding a catalog of 660 objects including several unusual sources such as an optical "flasher," a relativistically beamed quasar and a highly unstable magnetic binary system. High resolution X-ray spectroscopy of supernova remnants with data from the Einstein satellite is being used to perform plasma diagnostics of the interstellar material and stellar ejecta which were shock heated by the supernova explosion. Extragalactic studies include the identification of new X-ray quasars and active galaxies and measurements of the X-ray spectral properties of quasars at high redshift. A high resolution spectral study of active galaxies set limits on the quantity of diffuse matter surrounding the active nucleus. Several major instrumentation projects are underway including design and definition of instruments for the Japanese Astro-D mission, the X-ray Timing Explorer, the Advanced X-ray Astrophysics Facility, the Explosive Transient Camera, and the High Energy Transient Experiment.

2. Radio Astronomy

A central area of research has been the identification and study of candidate gravitational lens systems. The Very Large Array of the National Radio Astronomy Observatory and the International VLBI Network are being used to map the radio structure of objects initially identified in the extensive MIT-Greenbank radio survey of the sky. Modeling of the gravitational lens action can lead to an independent measure of the Hubble constant and can also map the dark matter distribution in the intervening galaxy and cluster. Follow up optical observations are also being performed to confirm the identifications. Another major program uses VLBI studies of dMe stars to make very precise position measurements that could reveal evidence of planetary or "brown dwarf" companions. There is also an ongoing program involving exploration of techniques of VLBI using space-borne antennae. The radio group continues its close collaboration with the Haystack Observatory, which is an integral part of the VLBI network.

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. Considerable progress has been made in a major program for determining the Hubble constant by a novel technique that involves measurements of the statistical fluctuations in the surface brightnesses of elliptical galaxies. To date, distance measurements have been made for nearly a dozen galaxies as far as the Virgo cluster. A continuing program of observational studies of galaxies will help trace the large scale structure of the universe. Observations of carbon stars in the Milky Way are being used to map the structure of our own galaxy, and to trace the amount and distribution of dark matter in the Galactic disk.

4. Cosmology and Gravitational Research Group

The Cosmic Background Explorer Mission (COBE) was successfully launched in November 1989. The project is a joint effort between the NASA Goddard Space Flight Center, the Jet Propulsion Laboratory, University of California at Berkeley, Princeton University and MIT. MIT has been involved with the project from its inception in 1974. Currently Professor Stephan Meyer and Professor Rainer Weiss in the Physics Department and the Center for Space Research are participants in the project from MIT. The mission is dedicated to observing the spectrum and angular distribution of the Cosmic Background Radiation (CBR), and the diffuse infrared emission in the universe between 300 and 1 m. All instruments are functioning properly and the mission will have surveyed the full sky for the first time by the middle of June 1990. Early results from the mission are: the spectrum of the CBR is now definitively established as Planckian to better than 1% in the decade spectral region embracing the blackbody peak, the spatial anisotropy of the CBR on angular scales from 7 to 180 degrees (aside from the dipole anisotropy due to the Earth's motion) is smaller than 10^{-4} and the full sky has been mapped with an absolute flux sensitivity of 10^{-13} watts/cm² steradian in the entire infrared. The mission is limited by the lifetime of cryogen to between 10 and 13 months. The full data from the mission is to be released to the scientific community four years after launch.

The Laser Interferometer Gravitational - wave Observatory (LIGO) project has passed three critical hurdles and is in the process of the fourth in June 1990. The project has been put in the President's budget as an FY 1991 new start for the NSF, it has passed peer review and has been approved by the National Science Board. It is currently being considered by the Congress. The project is a joint effort between the California Institute of Technology and MIT to design, construct and operate a pair of long baseline interferometric gravitational wave detectors at sites in the Western and Eastern United States. The LIGO is intended to open the new field of gravitational wave astronomy and is being carried out in coordination with two European consortia to establish a network of detectors for source position determination and gravitational waveform measurements. The project is under the direction of Professor Rochus Vogt of Caltech; Professor Vogt is also a Visiting Professor at MIT. The effort at MIT is guided by Professor Weiss of the Physics Department and the Center for Space Research.

5. Observational Cosmology

Following the launch of the Cosmic Background Explorer (COBE) in November 1989, the COBE group has been actively involved in preliminary data analysis and instrument calibration. The group's primary focus is the Far Infrared Absolute Spectrometer (FIRAS) which makes precise measurements of the spectral shape of the cosmic microwave background. The first results have just reached the literature, showing that the spectrum of the Cosmic Background Radiation (CBR) precisely fits that of a black body (contrary to earlier reports) of temperature 2.735 K, and that the "dipole term" is indeed a Doppler shift due to the solar system motion. The group also had a very successful flight of its balloon payload designed to measure small scale anisotropies in the CBR. The instrument achieves an order of magnitude improvement in sensitivity over previous detectors in the sub millimeter range. Preliminary analysis of less than 2% of the data show no anisotropies larger than one part in 20,000. A new apparatus that will operate at still smaller angular scales is being readied for use at the South Pole.

6. Space Plasma Physics

The space plasma group continued to interpret data from the Voyager spacecraft during its passage through the magnetospheres of the outer planets and through interplanetary space. The group is analyzing data from the very successful encounter of Voyager with Neptune in August 1989. This encounter completes Voyager's grand tour -- it is now heading for the magnetopause that separates the solar cavity from interstellar space. The Neptune encounter showed that this planet's magnetic poles are highly inclined to its rotation axis, and the plasma experiment helped to map that field and study the unusual interaction of a pole-on field with the plasma of the solar wind. The group is also developing a plasma experiment for the WIND spacecraft, which is one of several that will form the international Global Geoscience Program.

7. 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. These involve large scale N-body simulations performed on supercomputers and an innovative analytical technique for deducing the density of matter in the universe from the data on large-scale streaming motions of galaxies. 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 (that is creating a universe in the laboratory). Attention has turned to the question of whether a universe could be created by 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. Other work in cosmology includes a study of the quantum nucleation of strings, and domain walls during inflation, and elementary particle candidates for dark matter. 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 is now being 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 either by expansion of the companion star as it evolves or by shrinking of the binary system due to gravitational radiation. 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. Detailed calculations of the scattering interactions of low-mass X-ray binaries and binary radio pulsars in globular clusters with passing cluster field stars have also been carried out.

Atomic, Condensed Matter, and Plasma Physics Division

Condensed Matter

1. Single Electron Transistor

Because of advances in technology it is now possible to make semiconductor structures so small that they contain less than 100 electrons. This year, in a collaboration between MIT and IBM, such a transistor was fabricated, and it was discovered that its characteristics change by as much as two orders of magnitude whenever a single electron is added to it. This single-electron transistor consists of a GaAs layer, grown by molecular beam epitaxy, with a metal electrode on its surface. The metal electrode is patterned by electron beam lithography to define an active region that is about 1000 Å wide and 5000 Å long. As the voltage on the electrode is varied, the charge in the

active region of the GaAs changes. At temperatures below about 0.5 K, the conductance of the device, which measures its gain as a function of the charge in the transistor, consists of periodic resonances, one for each electron added to the transistor. The underlying physics that leads to such behavior is still not understood, but it apparently results from the Coulomb interaction between the electrons in the severely confined geometry. Since the resonances disappear above about 2 K, this single-electron transistor is not a useful device, but the behavior it exhibits was completely unanticipated and will certainly lead to new insights into the behavior of electrons in very small structures.

2. Crossover from Two to Three-Dimensional Behavior in Liquid Crystal Films

One of the fundamental precepts of solid state physics is that, in three dimensions, solids may have true long range periodic positional order whereas in two dimensions the positional order must decay to zero at large distances. This difference between two and three dimensions should manifest itself directly in an x-ray scattering experiment. Specifically, the x-ray diffraction pattern from a three-dimensional solid should be composed of a set of delta functions $\delta(\vec{Q} - \vec{G})$, where G is a reciprocal lattice vector, together with $|\vec{Q} - \vec{G}|^{-2}$ tails due to thermal fluctuations. In two dimensions, on the other hand, because there is no long range order, there are no delta-function Bragg peaks. Instead, one should observe a set of power law singularities of the form $|\vec{Q} - \vec{G}|^{-2+\eta}$. Both of these forms have been observed in previous experiments by ourselves and others. However, to-date no one has addressed directly the question of how one goes from two to three dimensions.

To probe this issue experimentally, we have grown high quality single crystals of the smectic I crystal phase of 8OSI (racemic 4-(2'-methylbutyl)phenyl 4'-(octyloxy)-(1,1')-biphenyl-4-carboxylate). The crystals were in the form of free standing films with thicknesses of 5, 14, 18, 90, and ~ 1000 layers. X-ray scans through the (100) Bragg peak position for these films show a dramatic dependence on thickness. Only the 1000 layer film may be described by the traditional 3d form-delta function plus q^{-2} tails. None of the thinner film profiles can be described by this form. The thin film data are, however, adequately fit as power-law singularities $|\vec{Q} - \vec{G}|^{-2+\eta}$. We find experimentally that to a good approximation $\eta \sim 1/n$ where n is the thickness of the sample. This behavior is predicted by a simple harmonic model. These experiments thus exhibit clearly the manner in which the structure evolves from two to three dimensions, that is, the x-ray line-shape and thence the underlying positional correlations evolve continuously as the thickness grows. Empirically this evolution is well described by a power law form, $r^{-\eta}$, with $\eta \rightarrow 0$ as the thickness becomes large.

3. Reconstruction of Metallic Surfaces

A remarkable feature of metallic and semiconductor crystals is that the geometrical arrangement of atoms on a free surface may have a fundamentally different symmetry than the arrangement of the underlying bulk atoms. This effect, called reconstruction, is particularly dramatic for Au(001) and Pt(001) surfaces, where the topmost atomic layer forms a close-packed, hexagonal lattice (the overlayer) on the top of the bulk planes of square symmetry (the substrate). The overlayer and the substrate are incommensurate; there is, however, a definite orientational relationship between the two lattices. Recent x-ray scattering experiments have characterized the orientational epitaxy of the Au(001) and Pt(001) surfaces as a function of temperature. A new understanding of orientational phase transitions has emerged from this study, as well as some new unanswered questions. More generally, understanding the atomic mechanisms of orientational epitaxy has broad applications in the areas of thin film growth and artificially-structured materials.

The phase behavior of both surfaces is remarkably similar. Near the bulk melting temperature (T_m), the surface is disordered. On cooling to $\sim 0.9 T_m$ there is a first-order phase transformation into the hexagonal phase. On further cooling, there is a

range of temperature in which the two lattices remain aligned. However at $T_C=0.8 T_M$, there is an onset of rotation. For the Au(001) surface, the rotational transition is discontinuous. Rotated domains appear with a fixed rotation angle of 0.80° . On further cooling rotated domains grow at the expense of unrotated domains, but there is always coexistence. In contrast, for the Pt(001) surface, the observed rotation angle is a continuous function of temperature and there is no coexistence with unrotated domains. At lower temperatures the rotation angle saturates at 0.75° . However, careful examination of the diffraction pattern in this regime reveals that there are peaks displaced from the substrate high symmetry direction by two distinct angles, indicating the coexistence of domains with different rotation angles. The second rotation angle on the Pt(001) surface is 0.7° . Domains with this orientation appear first at $\sim 0.7 T_M$ at a discontinuous transition.

According to the current theory of these phase transitions, there is a definite relationship between the rotation angle and the incommensurability between the overlayer and substrate. There is a number of instances for which this theory accurately describes the orientational epitaxy of an adsorbed layer. In contrast, the predicted rotation angle for the Au(001) and Pt(001) surfaces is 6.8° , which is approximately ten times the observed room temperature value. Furthermore, for both the Au(001) and the Pt(001) reconstructions there is a change in the rotation angle with no change in the incommensurability. That the current theory cannot describe the continuous rotational transition of the Pt(001) surface is particularly striking. However, a simple mean-field theory has been developed at MIT which incorporates the effect of orientational fluctuations and is able to quantitatively account for the observed behavior. This then provides the first clear example of a temperature-driven rotational transition. The same theory is able to predict a first-order transition for the Au(001) surface with slightly different parameters. It remains to understand the coexistence of the more than one overlayer rotation angle.

4. Transport Properties of High Temperature Superconductors

Since the discovery of the high T_C copper oxide superconductors over three years ago, it has become increasingly evident that strong repulsion and correlation between electrons play a crucial role which must be accounted for in any attempt to understand these materials. A key feature of this class of compounds is that the introduction of carriers to the copper-oxygen planes by doping turns an antiferromagnetic insulator into a metallic superconductor with short range antiferromagnetic order.

Evidence has accumulated that contrary to conventional superconductors, the high temperature metallic state of the high T_C superconductors behaves quite differently from conventional metals, which are well described by Fermi liquid theory. Instead, transport properties such as conductivity and Hall effect display anomalies which are in apparent contradiction to the recent observation of a Fermi surface by angular resolved photo-emission experiments. Our research has focussed on the theoretical understanding of this anomalous metallic state and we have developed a model which explains many of the unusual features observed experimentally. The model is based on a description of the short range antiferromagnetic state as a coherent superposition of spin singlets (the resonating valence bond state of P. W. Anderson) and the recognition that low lying excitations of this state should be described by a gauge theory. The gauge fields, which formally resemble electromagnetic fields, describe the local spin fluctuations that result when three neighboring spins are not co-planar. The fluctuation in the spin quantization axes leads to incoherence in the propagation of a charge carrier, which results in anomalous transport properties. We concluded that the metallic state in the high T_C superconductors are not described by conventional Fermi liquid theory. It is also clear that an understanding of the metallic state is prerequisite for an understanding of the mechanisms of superconductivity itself.

Atomic, Molecular and Laser Physics

1. Precision Mass Spectroscopy of Ions

Two separate advances in atomic physics, ion traps and separated oscillatory field spectroscopy, have been applied to the precise measurement of atomic masses, raising the state of the art for precision in mass measurement to 4×10^{-10} . This is a first step towards the ultimate goal of 10^{-11} or better. Such capability would permit a variety of experiments which address issues in both fundamental and applied physics, such as measuring the rest mass of the neutrino, determining Avogadro's number accurately enough to replace the current single mass standard (maintained in Paris) with one realizable in any laboratory, and ultimately determining the energy of chemical bonds from the "lost" mass of a molecule relative to its constituents.

The experimental approach is to make ion cyclotron resonance measurements on a single molecular or atomic ion in a Penning trap, which consists of a highly uniform magnetic field with axial confinement provided by weaker electric fields. Ions are monitored via the currents they induce in the trap electrodes as they oscillate along the magnetic field lines. Working with only a single ion is essential: space charge from other ions would lead to undesired frequency shifts. Detecting the $\sim 10^{-15}$ amp induced currents required developing superconducting electronic components as well as harnessing the power of a superconducting quantum interference detector. As a result, the state of the art in mass spectrometer sensitivity was advanced several orders of magnitude to its ultimate limit: a single ion.

Precision is currently limited by imperfections and temporal instabilities of the magnetic field. Achieving 10^{-11} precision in the mass measurement requires either dramatic improvements in field stability, or else simultaneous comparison of two different ions (with two ions of equal charge, the ion-ion perturbations are very similar for each ion and hence do not introduce significant uncertainty in the mass ratio). A single CO^+ ion and a single N_2^+ ion have been trapped simultaneously, suggesting that the latter approach is feasible. This approach has the intrinsic advantages of a mass balance over a spring scale.

Plasma

1. Noise in Free Electron Lasers

A complete understanding of the physics governing the frequency spectrum and temporal evolution of electromagnetic pulses is essential to the development of a new source of coherent radiation. In atomic and molecular lasers short pulse phenomena, such as nonlinear self (spontaneous) spiking, a wide range of mode-locking mechanisms, and soliton formation, have been investigated. In the free electron laser (FEL), radiation bursts, or spikes, have been studied in the nonlinear regime.

In contrast, new observations and theory have been carried out at MIT on FEL operation near oscillation threshold which focus on the linear evolution of micropulses of radiation that are initiated by shot noise on the electron beam. The measurements are conducted with a ring oscillator operating in a frequency range between 8 and 11 GHz, well before saturation and with low overall system gain (less than 3dB). A series of micropulses are observed that have a temporal separation corresponding to the radiation transit time (~ 40 ns) in the ring, and widths (2 - 4 ns) corresponding roughly to the slippage time between the electrons and the radiation. Placing a bandpass filter (9.6-10.2 GHz) at the output coupler reveals that groups micropulses combine into a macropulse, of about 1 ms duration, with a bell-shaped envelope. Although the macropulses occur at random times, their appearance is correlated with observed current fluctuations in the electron beam.

The micropulse evolution in the FEL ring oscillator is studied theoretically within the framework of the Maxwell-Klimintovitch formalism. The fundamental bell-shape macropulse resembles the temporal Green's function (the impulse response) of the FEL oscillator.

Theoretical predictions of the micropulse width and separation and the bell-shaped macropulse envelope agree with the observations.

These studies have increased our understanding of the FEL temporal behavior and its coherence build up. Furthermore, they suggest that, by triggering current spikes on the electron beam, one may generate trains of very short, tunable micropulses both in microwave and optical free electron lasers.

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 difficult 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.

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 is now in preparation. These are aimed at clarifying the dynamics of the short range nuclear force. A set of out-of-plane spectrometers is being developed for this purpose.

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. Following this successful measurement, we envision a continuing program of parity violation experiments. The next such experiment will be sensitive to strange quark components in the proton.

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 now being analyzed.

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 available for research 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. This is accomplished by using the SHR to manipulate the time-structure of the pulsed beam provided by the accelerator. Many of the needed detectors and the polarized beam are available.

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. There is considerable activity in this field, for example, at Argonne, Caltech, Harvard, Indiana, MIT, Oak Ridge, Princeton, and Wisconsin. 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. In considering potential developments at Bates, the Nuclear Science Advisory Committee has stressed that the "combination of internal target capability and polarized beams for addressing important new areas...will be unique in the world."

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. With the South Hall Ring experimental initiative at Bates and the major new facility at CEBAF, the American basic research community will have at its disposal unmatched capabilities built upon novel technologies.

2. Relativistic Heavy Ions

The Heavy-ion Group is a large part of the E802-E849 collaboration, exploiting 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 and yielding important tests of Quantum Chromodynamics (QCD), the theory of the strong interaction. In each 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 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. Experiments during the coming year will help elucidate the dynamical origin of this result. To facilitate this, a selective K^+ trigger has been implemented for the Spring 1990 run. The MIT group is also improving the E802 tracking detector system as well as designing a new system that can exploit the much heavier and energetic (2700 GeV) gold beams that will become available when the AGS booster synchrotron is completed in 1991. This will provide the opportunity to reach even higher matter/energy densities. Planning for experiments at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven are underway, with construction of RHIC planned to begin during 1991.

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 and the Gran Sasso (GSL) at L'Aquila, Italy.

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 inaccessible to other techniques.

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 and this subsystem is now essentially complete. The remainder of the detector is now also rapidly coming together. The accelerator group is now preparing apolarized electron beam preparatory to SLD running later this year. 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 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 and 2) Participation in the preparation of a proposal for a major detector for Superconducting Super Collider. In this connection the group has undertaken detector research and development and plans to participate in a current hadron collider experiment at FNAL.

c. Lepton Quark Studies Group

The LQS group is continuing its collaboration on the SLD experiment, which is to be performed with the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is participating in the commissioning phases of the Central Drift Chamber, and is also involved in the commissioning of the polarized electron beam. Tracking data from this drift chamber is to be used in conjunction with calorimeter and vertex detector information, allowing for the identification of various charged particles. This identification is crucial in the search for any new fundamental particle and in establishing the possible existence of new composite particles such as heavy-quark mesons and new gauge-like bosons. Combined with the 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. The detector is scheduled for installation into the beam line near the end of 1990 and data is expected to be taken in mid-1991.

d. Electromagnetic Interactions (EMI) Group

The EMI Group has built a large precision detector at the 100 GeV electron-positron accelerator, LEP in Geneva, which began operating in 1989. The group leading the large collaboration which involves 350 Ph.D. physicists from 12 nations to detect photons, electrons, and muons precisely. The experiment is the first large scale collaboration between physicists from the Soviet Union, the People's Republic of China, and the United States. The experiment is proceeding according to schedule and started data-taking by the time of the first LEP beam.

The experiment has detected 70,000 events from the novel Z0 particle, the electro weak force carrier. About 10 new results have been published in the last six months, more data are being collected. The purpose of the experiment is to understand the origin of the masses of all particles observed.

The Group is leading an effort to propose an experiment at the new super collider (SSC).

e. Proton-Antiproton Collision Group

This group is a member of the UA1 Collaboration at CERN. After the discovery of the W and Z weak bosons in 1982-9183, a large amount of data was collected to study further the properties of the W and Z bosons, to search for new quarks, new leptons, supersymmetric particles, etc... Muon data are now used to study b-quark production, BB mixing, and to search for exclusive decays of B mesons involving J particle production. The group has built and is operating a large emulator farm at MIT for data analysis. They are also involved in the construction a novel type of calorimeter using uranium and a liquid: tetramethylpentane. More specifically, this group is building a position detector for precision study of shower properties. This state of the art detector has possible applications for use in future colliders such as SSC.

Nuclear and Particle Theory Division

1. Particle Theory

This was another very active year with advances made in particle theory, field theory and also in the theoretical basis of quantum mechanics.

Interest in particle theory has focused on the structure function associated with the inelastic scattering in polarized nuclear targets. When the nuclear targets have spin one or larger, new structure functions are available for experimental study. The general theoretical basis for such investigation has been developed. Members of the particle theory group have been working on problems in lattice field theory and the theory of

strong interactions based upon QCD with members of the nuclear theory group and this work is described in the nuclear theory section.

Work on the possible role of quantum tunneling in the creating of "baby universes" has been actively pursued by theorists at many places this year. Since this problem involves an application of the as yet under-developed quantum theory of gravity, it has proved to be a very controversial subject. Theorists in our group have made an attempt to answer these questions in the most conservative way as the consequence of well-tried semi-classical methods. This attempt has led to more general investigations of the "sum over histories" formulation of quantum mechanics, in particular for quantum systems enclosed by boundaries and spin systems.

Investigation of the quantization of gravity has recently been of great interest at many places. Most have been considering first the problem in lower space dimensions, gravity in one space plus one time dimension. At MIT, as part of a general and pioneering program of the study of quantum field theory in two space plus one time dimensions, this subject has been actively pursued along with other questions associated with topology and "anomalies."

Although the theory of superstrings as a "theory of everything" is no longer as fashionable as it was a few years ago, as an example of the relativistic quantum mechanics of extended systems, it is the simplest and so far the only example which has been extensively investigated. The quantum mechanics of interacting closed strings has been one which has been most actively studied at MIT. It is the string theory which incorporates the generalization to strings of classical general relativity. During the past year, at MIT it has been proved that just as for general relativity the string theory is necessarily infinitely non-linear. The rules for this non-linear theory have been completely determined and have very interesting relationships to general mathematical theories of geometry. Conformal field theory in one-space, one-time dimensions is an off-shoot of string theory which has interested a significant number of our group. As yet the problems in this area have been mostly technical. Hopefully, in the future the technical successes will be related to the necessary physical applications to string theory.

In summary, the MIT group has been very successful in the investigation of many subtle aspects of the quantum theory of relativistic systems. The subject of particle theory has been more mathematical than in the past, partly because of the great success of the "Standard Model" in accounting for all known phenomena. Many in the group await impatiently for their experimental colleagues to uncover new phenomena which defy explanation within the context of this model.

2. 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 destructive interference of trajectories contributing to the quark propagator. A variety of analytic approaches to QCD are being explored, ranging from classical solutions and variational calculations to a mean plaquette approximation and a truncated cumulant expansion. 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. 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 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 in formation time effects, dynamic plasma screening and final state interactions. Other studies of possible signatures include dilepton production in a non-equilibrium plasma and phi production. A flux tube model of heavy ion collisions developed previously was extended to include plasma oscillations and hadronization.

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, and a new semiclassical approximation to it reveals the origin of semiclassical "scars" observed in quantum eigenstates. 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. Stochastic techniques, which have been exploited for a variety of many-body problems ranging from non-relativistic nuclear models with static interactions to quantum spin systems and lattice gauge theories, have been extended to circumvent the long-standing problem associated with antisymmetry for few-fermion systems in any spatial dimension.

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, with particular emphasis on the deuteron, measurement of current distributions in rotational nuclei, radiative capture, and understanding pion production near threshold. Other topics include the study of meson exchange currents, relativistic generalization of the Coulomb sum rule, and scaling in quasielectric scattering.

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 using a hybrid bag model with external meson fields and a flux tube quark model, with the goal of exploring 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 QED in strong fields and finite chemical potential, topological structures and renormalization in field theory, quantum spin systems, and novel half-integer angular momentum solutions in quantum mechanics.

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 its 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 three major research programs, oncogenes and mammalian genetics, cell biology, and immunology. Currently 159 people work in the Center who are distributed between the research laboratories of 11 faculty. The total research activity in the Center has grown by 6.9 percent over the past year. This growth represented expansion of ongoing programs.

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 facilities, specialized laboratories and partial support for new faculty) is a center core grant from the National Cancer Institute. This core grant runs for a five-year term and was successfully renewed for years 19 through 23 during the fall of 1989. The Center's success was 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 47 fully funded projects not including over half a million dollars of competitive support in fellowships for postgraduate studies. The Center gained additional laboratory research space this spring. The 2,253 sq. ft. of acquired space will be renovated in the fall for research in immunology and vertebrate development. The Center has an excellent program in immunology with two senior faculty, Drs. Herman Eisen and Susumu Tonegawa, and Dr. David Raulet, whose promotion to tenure will be effective as of July 1, 1990. Future appointments will strengthen this basis with an emphasis on cellular aspects of the system. For example, how are immune cells selected or educated to recognize self from non-self antigens? In regards to vertebrate development, Dr. Nancy Hopkins is currently on a sabbatical at Max-Planck Institute in Germany 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 will initiate research on this interesting system in some of the new space.

It is always a pleasure to have a junior colleague promoted to tenure at MIT. Dr. Raulet has just been informed that he will be promoted to tenure in the coming year. Dr. Raulet's research has been important in establishing the developmental program of a new subgroup of T cells in the immune system. The cell surface receptors for recognition of antigens expressed by this subgroup are encoded by groups of genes termed γ and δ . Dr. Tonegawa's laboratory discovered the existence of this group of genes and the two groups initially collaborated in the research. More recently, Dr. Raulet participated in the analysis of the immune system of a strain of mice created by Dr. Rudolf Jaenisch of the Whitehead Institute. In this mouse strain a gene critical for the function of T cells in the immune system was inactivated by a specific targeting procedure. The distribution or type of T cells in the new variant mouse is highly perturbed. Dr. Raulet is studying the nature of the imbalance in the immune system which will lead to insights into diseases such as cancer and autoimmunity. Dr. Brent Cochran, a faculty member in the Center's tumor virology and genetics program, who is studying the signals that control the division of cells, will be promoted to associate professor during the coming year. Other honors afforded the faculty of the Center during this past year were: Dr. Phillip A. Sharp's election to Associate Member of EMBO and presentations of the Chirion Lectures at the University of California, Berkeley, and the Jacob Mager Lecture at the Hebrew University in Israel; Dr. Eisen's presentation of the Distinguished Immunologist Lecture Series at the University of California Medical Center, San Francisco; Dr. Hopkins' receipt of the Humboldt Research Award; Dr. Tonegawa's receipt of the Distinguished Investigator Award of American College of Rheumatology and the Rabbi Shai Shacknai Memorial Prize in Immunology and Cancer Research, Jerusalem.

The faculty of the Center fulfill critical roles in the educational program of the Department of Biology. We were all honored by the selection of our colleague, Dr. Richard Hynes, to Department Chairman. In addition, Dr. Frank Solomon received the Graduate Student Council Teaching Award in Biology for 1990.

Among the several important advances during the past year, the isolation of the Wilms' anti-oncogene stands out as the distinct event. The childhood malignancies, retinoblastoma and Wilms' tumor, were originally identified by Knudson at Fox Chase as situations in which the inactivation of anti-oncogenes is likely to play a central role in tumorigenesis. The development of Wilms' tumor, a malignancy of embryonic kidney cells, was associated

a Wilms' tumor. Over the past decade, Dr. David Housman's laboratory developed gene mapping and cloning strategies designed to identify the Wilms' anti-oncogene and this effort came to fruition this fall. The predicted structure of the polypeptide encoded by the Wilms' gene (designated WT1) contrasts significantly with the retinoblastoma (RB1) and p53 genes, the other previously characterized anti-oncogenes. WT1 encodes a polypeptide with a structure which strongly indicates that it will bind DNA with high sequence specificity. WT1 also contrasts strongly with RB1 and p53 in the tissue specificity of its expression. RB1 and p53 polypeptides are expressed in most tissues examined, while WT1 is only expressed at high levels in the embryonic kidney cells which give rise to Wilms' tumors. The DNA binding characteristics of WT1's structure suggest that this anti-oncogene controls cell proliferation by regulation of expression of other genes, probably those which are responsible for normal development of kidney cells. Dr. Housman speculates that perhaps other anti-oncogene proteins such as those encoded by RB1 and p53 may also suppress tumorigenesis by regulating the activity of genes controlling cellular proliferation. Enhancing the activities of anti-oncogenes in tumor cells or developing drugs which will functionally replace them might be an effective means of controlling some cancers.

The strength of the Center remains its attractiveness as an environment for the training of young scientists. The Center has 43 graduate and undergraduate students and 58 postdoctoral fellows/associates. The Center also benefited from a number of both national and international faculty-rank visitors during the past year: Drs. Hiroyuki Aburatani (Tokyo University), Annette Herscovics (McGill University) Hiromichi Ishikawa (Keio University), Gabriel Kaufmann (University of Tel Aviv); Yoshiaki Ichikawa (Kao Corporation), Harald von Melchner (University of Essen, W. Germany), Ann Chu (Temple University), Antonio Coutinho (Institut Pasteur), David Critchley (University of Leicester, UK), Werner Haas (F. Hoffman-LaRoche, Basel, Switzerland), Kouichi Ito (Ajinomoto Co., Inc., Japan), and Judy Lieberman (Tufts New England Medical Center). 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: Dr. Myles Brown, Instructor, Harvard Medical School and Fellow in Medical Oncology, Dana Farber Cancer Institute; Drs. David Fisher, and Daniel Haber, Fellows in Medical Oncology, Harvard Medical School and the Dana Farber Institute; and Dr. David Potter, Hematology Fellow, Brigham & Women's Hospital and Harvard Medical School.

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 new "mission-of-opportunity" programs, in which CSR will play a crucial role, have also been recently initiated by NASA. These are: ASTRO-D, a Japanese X-ray satellite for which CSR will supply 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. The recent successful launch of the German ROSAT mission provides an important new facility for the coming years.

Professor Hale Bradt and Dr. Ronald Remillard have completed a major catalog of 660 X-ray sources identified by HEAO-1, and continue to investigate the nature of these sources using observations at other wavelengths. Professor Claude Canizares and his colleagues have nearly 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, as are optical observations of these objects using the new MDM Observatory. Professor Walter Lewin and his collaborators at MIT and abroad are investigating the nature of low-mass binary X-ray sources by analysis of the quasi-periodic oscillations and bursts seen in their X-ray emission, using data from the European X-ray Observatory Satellite (EXOSAT). Professor George Clark and his student, working in collaboration with Dr. Fumiaki Nagase and others of his colleagues at the Institute of Space and Aeronautical Sciences (ISAS) in Tokyo, continue studying the atmospheric structure of the primary stars using GINGA observations of eclipsing X-ray binaries.

Advanced X-ray Astrophysics Facility (AXAF). AXAF is a major NASA mission of the "great observatory" series, scheduled for launch in 1997. 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. This effort 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. A group under Dr. George Ricker (CSR), Deputy Principal Investigator for ACIS, has continued collaboration with Dr. Barry E. Burke 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.

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 will provide 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 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. An engineering test unit was delivered to ISAS 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 1993/94. The HETE consortium, which also includes scientists from Los Alamos National Laboratory, the University of Chicago, CNES/CESR (Toulouse, France), the University of California (Berkeley and Santa Cruz), and possibly a Japanese group. 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 ejected from a Get-Away Special (GAS) canister carried into low earth orbit by the Shuttle. 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 nearly completed a study to demonstrate the feasibility of the Cheapsat concept.

X-ray Timing Explorer (XTE). This mission represents a relatively inexpensive NASA X-ray astronomy satellite program that is scheduled for launch in 1995 to study the time variability of celestial X-ray sources at time scales ranging from tens of microseconds to years. 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 contract to develop the instrumentation was signed in December 1989, and the design effort is now 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 began in May, 1987, under the supervision of Drs. Ricker and Vanderspek. Improvements to the software and hardware have been incorporated into the system, which has otherwise continued routine observations.

THE MICHIGAN-DARTMOUTH-MIT (MDM) OBSERVATORY

The MDM Observatory, located on Kitt Peak near Tucson, Arizona, comprises 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).

A Hartmann mask and a prime-focus camera, for use in testing the primary mirror of the Hiltner 2.4-m telescope, were constructed during the summer of 1989. Tests were carried out and analyzed during the fall and winter, indicating that 50 percent of the incident light is concentrated in a circle 1.1 arcseconds in diameter. Work has begun on the construction of a versatile "modular" spectrograph for the Hiltner telescope. The McGraw-Hill 1.3-m telescope remains heavily oversubscribed during moonless "dark" time.

Much of the work at MDM this year involved searches for the optical counterparts of stars, galaxies and clusters of galaxies discovered at other wavelengths. Professor Bradt, Dr. Remillard and students Grossan and Silber identified stars and active galactic nuclei in the HEAO-1 hard X-ray survey. Professor Bernard F. Burke and students Conner and Lehar identified galaxies associated with radio sources in the MIT-Greenbank 5-GHz Survey. Professor Lewin and student Magnier have searched the nearby Andromeda galaxy for the low amplitude variable stars which are thought to be associated with high mass X-ray binaries. Professor Richard Binzel (EAPS) has continued his photometric comparative study of near-Earth and small main-belt asteroids. Graduate student Luu (EAPS) has continued her work on the spectra of comets. Professor Paul Schechter has begun a project to look for faint quasi-stellar objects, "quasars," which may be associated with other brighter, better-known quasars.

RESEARCH IN SPACE PLASMA PHYSICS

Interplanetary and Magnetospheric Plasmas. The space plasma group, headed by Professor John Belcher with Professor Ralph McNutt and Dr. Alan Lazarus, is continuing to analyze and interpret the data received from the Voyager-1 and -2 interplanetary spacecraft, now traveling through the outer solar system. With Voyager 2 having undergone its last planetary encounter (Neptune, on August 25, 1989), the group is now concentrating on planning the "imminent" interstellar mission. After passing Neptune, Voyager 2 has turned southward but retains a significant outward velocity that will eventually take it through the heliopause, where the plasma environment is no longer dominated by the solar wind. There is great interest in comparing results to be obtained there by Voyagers 1 and 2 with the data being supplied by the Pioneer-11 spacecraft at a similar distance from the sun, but nearer the heliographic equator.

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. 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.

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 Faeed 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 using synthetic aperture radar (SAR) techniques at a resolution approaching 100 m, was launched May 4, 1989, and will reach Venus on August 10, 1990. 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 will be 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. As part of this effort, an MGN-dedicated digital processing laboratory has been set up in CSR. Planning for this mission now entertains operation for most of 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 topography of Mars at a lateral surface resolution of a few hundred meters, and with a vertical accuracy of several meters. This instrument, being developed at Goddard Space Flight Center, will be carried into orbit around Mars by the MO spacecraft, to arrive at that planet in the fall of 1993.

SPACE GEODESY

The space geodesy group, led by Professor Charles Counselman (EAPS), has developed several new methods for determining Earth-satellite orbits based on the radio-astronomical technique known as aperture synthesis. For these developments, MIT has been awarded U.S. Patent No. 4,912,475, entitled "Techniques for Determining Orbital Data."

RADIO ASTRONOMY

Professor Burke 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) project has passed three critical hurdles in the past year, and is in the process of overcoming the fourth. It is now an official "new start" with full approval of the National Science Foundation and National Science Board. The project consists of the design and construction of two identical 4-km-long interferometer sites in the continental US: one on the west coast in California, and one in the east, either in Maine or Louisiana. The site planning is being coordinated with European gravitational wave research groups, in order to optimize the utility of a possible global network. The project is under the control of Professor Rainer Weiss, and his associates at MIT, with the director, Professor Rochus Vogt, at the California Institute of Technology.

Cosmology Research. The Cosmic Background Explorer (COBE) Mission was successfully launched in November 1989, as a collaboration among the NASA Goddard Space Flight Center, the Jet Propulsion Laboratory, the University of California at Berkeley, Princeton University, and MIT. MIT has been involved in the mission since 1974, with Professors Weiss and Stephen Meyer playing leading roles. The mission is dedicated to observing the spectrum and angular distribution of the cosmic background radiation (CBR) at millimeter radio wavelengths, as well as the diffuse infrared emission between wavelengths of 1 and 300 μm . All the instruments are functioning properly, and the full sky had been completely surveyed (for the first time ever) by mid-June, 1990. Early mission results suggest that the CBR follows the Planck black-body curve to an accuracy of better than 1 percent, at least in the several octaves surrounding the spectral peak; that the spatial anisotropy of the CBR on angular scales between 7° and 180° is less than 0.01 percent; and have yielded a fairly deep, full-sky map in the infrared. The supply of on-board cryogenics will limit the mission's total duration to about a year.

AEROSPACE PHYSIOLOGY AND MAN-MACHINE SYSTEMS

Professor Laurence R. Young (AA), assisted by Dr. Charles M. Oman (AA), and their colleagues in the Man Vehicle Laboratory (MVL), has been preparing for two spaceflights scheduled to carry three MVL experiments into orbit during the forthcoming 1990-91 academic year. This first dedicated life sciences flight, designated Spacelab Life Sciences-1 (SLS-1), will refly some of the existing MVL visual/vestibular interaction equipment on shuttle flight STS-40. The first International Microgravity Laboratory flight, currently scheduled for early 1991, will include a test of the vestibular-ocular reflex under the guidance of Dr. Oman, as well as a human performance and anthropometry experiment that Professor Harold Alexander (AA) has taken over from Professor Steven Bussolari, formerly of MVL.

The MVL activity in expert systems ("PI in a Box") is now at full strength with the recruitment of Dr. Rajiv Bhatnagar as Research Scientist in the Laboratory and the addition of two more engineers to work with colleagues in this experiment at NASA Ames Research Center. This project, to provide a system that can advise astronauts directly as they carry out life science experiments in space, received its first preliminary test in conjunction with simulations of the upcoming SLS-1 rotating-dome experiments.

Academically, the year saw four graduate students associated with MVL complete their requirements for a master's degree, and two doctoral students finish their theses; one of the latter, Dr. Dan Merfeld, has subsequently joined MVL as a Research Scientist in support of spaceflight activities.

GORDON H. PETTENGILL

Experimental Study Group

The Experimental Study Group (ESG) finished its first year under the direction of Professor Vernon M. Ingram from MIT's Department of Biology, who took over faculty leadership from Professor J. Kim Vandiver in July 1989. The year was marked by an expanded curriculum in ESG (including new subjects in computer science, biology, and a 24 unit subject combining physics and philosophy) and a record high interest in ESG shown by first year students. The new subjects we offered complemented our standard curriculum in the science core and in humanities and social sciences. We look forward in the coming year to building on this year's successes in enrollment and curriculum development.

STUDENT STATISTICS

ESG enrolled 81 students this year for one or more terms (62 freshmen, 3 sophomore transfers, and 16 ESG upperclassmen). This is the highest figure in the twenty-one year history of the program. The 37 sophomores currently registered at MIT who had been in ESG as freshmen earned a median grade point of 4.2. This figure is higher than the corresponding figure for the entire MIT sophomore class for the ninth consecutive year. Seventy-six percent of our sophomores are majoring in the School of Engineering, 16 percent in the School of Science, and 8 percent in the School of Management. Compared to previous years, this represents a shift away from the School of Science and toward the School of Engineering, a shift which more closely resembles the profile of majors for the MIT sophomore class as a whole.

STAFF AND FACULTY

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 David Anick), 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 each term in ESG.

The ESG staff retained a great deal of continuity from last year, with ten out of thirteen staff members returning. The median length of time our staff members have been teaching at ESG is now four years. The physics staff included Professor Emeritus Robert Halfman, Dr. Peter Dourmashkin, Craig Watkins, and graduate student Daniel Zachary. The mathematics staff was headed by graduate student Harold (Hal) Sadofsky and included graduate student David Cape and ESG alumnus Victor Steinbok '87. The chemistry and biology staff was led by Professor Ingram who taught an ESG recitation section of SP01 Chemistry, Materials Science, and Biology in the fall term and SP02 Chemistry, Materials Science, and Biology in the spring. Melanie Holland '90 taught 5.11 Principles of Chemical Science in the fall, and an ESG recitation section of 5.12 Organic Chemistry in the spring. The humanities staff included Dr. Lee Perlman (who received his doctorate in

Political Science from MIT in the fall), Chris Thornton (who had taught previously in MIT's Writing Program), and Holly Sweet (who holds a lectureship in the School of Science).

Our chemistry, physics, and mathematics staff were assisted by 29 undergraduate tutors (most of whom had been in ESG as freshmen), four graduate student tutors, and one ESG alumnus. These tutors shouldered 40 percent of the teaching load at ESG, yet managed to maintain a 4.4 cumulative grade point average. One of our departing senior tutors, Kenneth Simons '90, won the Karl Taylor Compton award, in part due to the dedication and excellence he showed in his tutoring at ESG. We consider our undergraduate tutors to be one of ESG's finest assets and indispensable to the successful operation of our program.

ACADEMIC DEVELOPMENTS

As a result of efforts initiated primarily in the 1988-89 academic year, several subjects were offered for the first time at ESG. Dr. Dourmashkin and Dr. Perlman combined their academic specialties (physics and political philosophy respectively) in a 24 unit subject which provided students with an opportunity to study Physics within a political and social context as well as learn the more traditional problem set oriented approach. Through the use of experienced ESG tutors, we were able to offer an ESG recitation section for 1.00 Introduction to Computers and Engineering Problem Solving. Recitation sections for SP01 and SP02 were run by Professor Ingram, and a tutorial version of 7.01 General Biology was offered through the use of a student tutor under the supervision of Dr. Ingram.

For several years ESG has been offering undergraduate and advisor seminars, both for ESG students and for students in the regular curriculum. The discussion oriented format of these seminars and opportunity they provide for student participation and experiential learning have made them popular. This year we offered three seminars, including one that has been offered for the past four years at MIT (SEM051 Sex Roles and Relationships, co-taught by Ms. Sweet and Dr. Perlman). Dr. Perlman also taught a new undergraduate seminar, SEM065 Non-Violent Political Action. Professor Ingram developed a new advisor's seminar, SEM078 The Making of a Scientist, which he taught to his fall term ESG advisees. In addition, ESG also provided academic sponsorship for SEM069 Leadership and Teamwork, run both terms by MIT alumnus Hrand Saxenian '47. A total of 58 students (including 47 regular curriculum students) took part in one or more of these seminars.

Several staff members have been actively involved in other programs around the Institute. Dr. Dourmashkin, Mr. Sadofsky, Ms. Sweet, and Mr. Watkins taught in Project Interphase in the summer of 1989. Dr. Dourmashkin also taught physics in the Integrated Studies Program and in the Office of Minority Education, and Mr. Watkins assisted in the teaching of a laboratory oriented version of 8.01 Physics taught in the regular curriculum. Ms. Sweet continued to counsel women graduate students on a part-time basis in association with her doctoral work in Counseling Psychology. She also participated for her third year in the Freshman Interview Project, sponsored by the Office of Undergraduate Education. We consider the connection of our staff members with other areas at the Institute a fertile ground for the development of new ideas in education.

Three of our freshmen received scholarships for independent summer work which they designed: Emily Houh '93 (a public service fellowship for tutoring children of homeless women), Samie Jaffrey '93 (an Eloranta fellowship for studying the philosophical background of the Iranian revolution), and Armando Razo '93 (the Carroll Wilson award for studying science and technology policy in Mexico). In recognition of the initiative shown by many of our students in both academic and non-academic activities, we will be establishing an annual ESG prize, funded by contributions from ESG alumni, which will be given to an ESG student currently enrolled at MIT who develops the best independent study project each year.

ESG continues to provide a home for students and staff at MIT who are interested in a more individualized 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.

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. The Laser Research Center grant was renewed by NSF and the Laser Biomedical Research grant was renewed by NIH. A major new research grant in the field of laser angioplasty under the support of GV Medical Corporation in Minneapolis has begun. Several new facilities were set up. The nanosecond transient absorption apparatus was successfully assembled and was used in several research projects. A new FT-IR and FT-Raman apparatus was purchased as part of the Laser Biomedical Research Center facilities. Two new pulsed Nd:YAG lasers were added to Tissue Ablation Laboratory.

Dr. Firooz Partovi and Dr. Young Park, Research Scientists at the laboratory, have left to take new positions elsewhere.

MIT LASER RESEARCH CENTER

The MIT Laser Research Center (LRC), a National Science Foundation Regional Instrumentation Facility housed in the Spectroscopy Laboratory, is now in its tenth year of operation. The LRC enables researchers from academic, industrial and other types of institutions to pursue research in broad areas of laser spectroscopy and dynamics, to develop new types of coherent sources and techniques, and to perform diagnostic studies of various substances and materials. Its unique facilities, which include a broad range of lasers and ancillary equipment, constitute one of the largest and best-equipped centers in the United States devoted to spectroscopic research.

MIT LASER BIOMEDICAL RESEARCH CENTER

The MIT Laser Biomedical Research Center (LBRC) is now in its fifth 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.

New laboratories and new equipment have been added to facilitate the programs of the two Centers. 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 tunable laser facility which provides intense pulses of light continuously tunable over the wavelength range 216-4500 nm; a picosecond dye laser facilities 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; 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 a transient digitizer, fluorescence microscopes and several optical multichannel spectral detectors.

RESEARCH HIGHLIGHTS

Professor Steinfeld has been using time-resolved diode laser absorption (TRDLA) spectroscopy to characterize the physical and chemical properties of reactive molecular species. Dr. Osamu Suto, a visitor in the laboratory from the Power Reactor and Nuclear Fuel Development Corporation, Tokai-Mura, Japan, during 1989, has used the TRDLA technique to characterize difluorocarbene radicals produced in the excimer-laser photolysis of tetrafluoroethylene. In future work we shall apply this technique to study the photolysis process in carbonyl halides, which may participate in upper-atmosphere ozone cycles.

Professors Robert W. Field and Robert J. Silbey and Postdoctoral Associate Dr. Xinsheng Zhao of the Department of Chemistry have initiated a new experimental study of the dissociation dynamics of the formyl radical (HCO) by SEP. The goal of this work is to push the assumptions of statistical unimolecular reaction rate theory to the quasi-stationary state limit in an energetic region where the density of states is low enough so that individual scattering resonances can be spectroscopically assigned. HCO is produced by 308 nm excimer laser photolysis of acetaldehyde. Fluorescence excitation studies demonstrated a high fluorescence quantum yield for the \tilde{B} state, which was used as the intermediate in our SEP experiments. The \tilde{B} state has the additional virtue of providing Franck-Condon access to all normal modes [states are labeled (C-H stretch, C-O stretch, bend)] of the ground state of HCO, so that a systematic search for mode-selective chemistry is possible. Preliminary SEP experiments demonstrate a dramatic change in dissociation lifetime for two states just above the dissociation barrier. A measurement of the widths of the SEP transitions shows that the (0,4,1) resonance at 8,478 cm^{-1} has a lifetime of 0.88 ps while the higher energy (0,5,0) resonance at 9,091 cm^{-1} has a longer lifetime of 5.7 ps. Systematic studies of the effect of differing vibrational and rotational excitations on dissociation are in progress.

Professors Field and Silbey initiated a new experimental study of excited electronic states of the iso-electronic molecules acetylene (HCCH) and hydrogen cyanide (HCN). In HCN, the dipole moment of the first excited singlet state has been measured from the Stark effect on the vacuum ultraviolet $A(010)^1 \leftarrow X(00^0 0)$ fluorescence excitation spectrum to be $2.7 \pm 0.4D$. This value is substantially larger than predicted by molecular orbital theory or ab initio calculations, and will necessitate a substantial refinement of our understanding of the electronic structure of HCN. In HCCH, the weakly pre-dissociated E^1B state has been studied by uv-uv double resonance. The existence of this state has been questioned by recent ab initio calculations, so a re-interpretation of much of the electronic structure of acetylene is necessary. Since this state had previously been observed by one-photon absorption from the ground state, this proves the molecule is rigidly non-centrosymmetric and establishes the linear electronic configuration as $(2\sigma_g)^2(2\sigma_u)^2(3\sigma_g)^2(1\pi_u)^3(1\pi_g)$. A preliminary rotational analysis strongly suggests that the equilibrium geometry 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 configurations. Studies of the predissociation mechanism and a complete rotational and vibrational analysis are in progress.

Professor Field and Silbey continue their studies of vibrational dynamics on the ground electronic surface of acetylene (HCCH). Stimulated Emission Pumping (SEP) spectra of HCCH above $14,000 \text{ cm}^{-1}$ indicate that the rotation-vibration separation has partially broken down. Throughout the $15,000 \text{ cm}^{-1}$ - $16,000 \text{ cm}^{-1}$ region, the density of states observed by SEP exceeds the total calculated by an anharmonic direct count by up to a factor of two, indicating substantial vibrational mixing. Surprisingly, statistical measures borrowed from nuclear physics to test for the quantum analog of classical chaos indicate that the spectrum of acetylene at $15,000 \text{ cm}^{-1}$ is not as rigid as predicted for strongly chaotic dynamics. A collaboration with Dr. Kaoru Yamanouchi, of the University of Tokyo (Japan) has partially elucidated the short time (30 fs to 2 ps) dynamics of acetylene by a comparison of the low resolution Dispersed Fluorescence (DF) and 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 second set of two progressions in the ν_4 and ν_5 modes is built on either the C-H stretch (ν_1) or 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. A comparison of the SEP and DF spectra having the same upper rovibronic levels reveals that a single feature assigned to one bright state in the DF spectrum is composed of 10-40 peaks in the SEP spectrum. A notable feature of this analysis is the 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. Further experiments with goals of identifying the unassigned progressions, searching for additional resonances, and determining the timescale of chaos are under way.

Professor Keith A. Nelson of the Department of Chemistry is carrying out nonresonant and resonant Raman spectroscopy of several condensed-phase materials. In collaboration with Dr. Douglas Hall of Corning Glass Works, he is examining several nonlinear optical glasses. We have recently obtained Raman spectra of these glasses using both green and

red excitation light. The Raman spectra are useful in understanding the role of "local" vibrational motion in the femtosecond optical responses of the glasses. He is also examining photochemically reactive crystals and liquids in an effort to elucidate the reaction coordinates along which molecules move in the first few hundred femtoseconds after photoexcitation. Recent resonance Raman results on the solution phase organometallics $\text{Cr}(\text{CO})_6$ and $\text{Mn}_2(\text{CO})_{10}$ reveal possible reaction coordinates for both species. Further experiments on these samples, as well as the excimer-forming crystals pyrene and perylene, are planned.

Professor Stephen J. Lippard of the Department of Chemistry utilizes resonance Raman spectroscopy to study oxo- and hydroxo-bridged polynuclear iron centers in proteins and related model compounds. By monitoring the isotopic shift of the Fe-O-Fe symmetric stretch, Drs. William Tolman and Robert Beer of the Department of Chemistry have studied the degree of ^{18}O incorporation into the oxo bridge in reactions with labeled water and dioxygen of a series of dinuclear iron complexes. The effects of different ligand environments on the resonance enhancement of the Fe-O-Fe symmetric stretch in the $\{\text{Fe}_2\text{O}\}^{4+}$ core have also been monitored.

Professor Mark S. Wrighton of the Department of Chemistry and his collaborators have been involved in studies to determine the factors governing inter- and intramolecular excited state electron transfer. In the past year research has addressed the question of establishing the relative importance of energy transfer and electron transfer when both processes are thermodynamically possible. Studies in this regard have been directed toward the use of ferrocene as a triplet quencher or as an electron transfer donor to excited states of transition metal complexes or porphyrin molecules. Depending on the substituents attached to the cyclopentadienyl rings of the ferrocene, electron transfer is more or less efficient, in a manner consistent with the rate dependence on energetics of electron transfer. Fundamental studies of this kind involve the use of transient Raman, transient absorption, and fluorescence life-time measurements.

Professor Steven R. Tannenbaum and Drs. Billy W. Day, Paul L. Skipper, Brahmdeo Dewprashad, and Nigel K. Brown of the Department of Chemistry and the Division of Toxicology have continued their studies on fluorescence spectroscopy of protein and DNA adducts of chemical carcinogens in collaboration with Drs. Ramachandra R. Dasari and Mark M. Doxtader of the Spectroscopy Laboratory. Room temperature excitation/emission and synchronous scanning, as well as cryogenic line-narrowing fluorescence techniques have been used to help identify and quantify adducts formed between the active metabolites of polycyclic aromatic hydrocarbon carcinogens and the blood protein hemoglobin. Adducts have been detected in both adults and fetuses exposed only to ambient environmental levels of the carcinogens benzo[a]pyrene and chrysene. These types of studies have been expanded to include the measurement of the adducts found in the blood of flounder from Boston Harbor. Work toward the development of a fluorescence method of measuring exposure to oxoethylating carcinogens has also been initiated.

Professor Steven R. Tannenbaum of the Department of Chemistry and the Division of Toxicology and Drs. Billy W. Day and Paul L. Skipper of the Division of Toxicology have continued their studies on fluorescence spectroscopy of protein and DNA adducts of chemical carcinogens in collaboration with Drs. Ramachandra R. Dasari and Mark M. Doxtader of

the Spectroscopy Laboratory. Fluorescence line narrowing spectroscopy (FLN) has been utilized to spectrally resolve polycyclic aromatic hydrocarbons and etheno adducts at the subpicomole range. In combination with other analytical procedures FLN has assisted in adduct site identification in human globin. Using internal standards and factor analysis, a series of epidemiological studies are being conducted to ascertain adducts levels and identities in human tissue.

The tensile strength of interfaces between micron thick protective SiC coatings and C fibers are of fundamental interest in the development of tough and damage resistant composite materials. An experiment is being developed by Professor Ali S. Argon of the Department of Mechanical Engineering in which this strength can be measured by laser spallation. In this technique, a laser pulse of about nanosecond duration and sufficiently high amplitude is converted into a narrow pressure pulse by absorption in a thin opaque layer sandwiched between a quartz plate and the back surface of the substrate containing the coating. Upon reflection from the front surface containing the SiC coating, the pressure pulse will become tensile at the interface and spall off the coating if the stress amplitude is large enough. Scoping experiments have demonstrated that SiC coatings of 1-2 μm thickness can be spalled off readily in this manner, and experiments with piezo electric crystals have established that the profiles of the stress pulses can be accurately characterized. Experiments are now in progress on the actual measurements of interface strengths.

Professors Forbes Dewey of Mechanical Engineering and August Witt of Materials Science are investigating the use of new crystal structures to produce nonlinear optical effects. This program, sponsored by the U.S. Navy, has succeeded in using the rotational twin defects in CdTe and other similar crystals to enhance the production of second-harmonic radiation from CO₂ lasers. Applications of this technique could be valuable to wavelength-tunable laser spectroscopy sources, to laser communication transmitters, and to multi-wavelength atmospheric probes. Experiments are continuing on testing the optical properties of crystals grown by Professor Witt and Dr. Piotr Becla, a principal team member.

Professor Toyochi Tanaka and Dr. Sridhar Gorti, both of the Department of Physics, have been involved in the observation of molecular Brownian motions within single live cells, in situ, by making use of microscope laser light scattering spectroscopy. In their studies emphasis has been placed on elucidating the mechanisms associated with laser-tissue interaction and primary bile secretion at the cellular level. In particular, the effects of laser irradiation on hemoglobin (Hb) at a laser output wavelength of 577nm have been determined in terms of Hb diffusivity within single red blood cells exposed to different dose irradiance. The results of these experiments evidenced a threshold laser dosage at which Hb denaturation occurred. The data obtained may well establish new guidelines for the treatment of portwine stain disease by the technique of selective photothermolysis. The physical-chemical state of primary bile secreted within the canalicular space of isolated rat hepatocyte couplets was studied in order to gain further insight into the nature of human gall stone formation. Several physiologic and pathologic agents were used to determine the rate of primary bile secretion under cholertic and cholestatic conditions. Unlike studies involved in determining the physical-chemical state of distal ductal bile, the study of primary bile secretion had evidenced changes in biliary lipid aggregates at the cellular level and literally

"at the moment of birth". of bile.

Professor David Pritchard of the Department of Physics and his colleagues have obtained the first radio frequency spectra from atoms confined in a magnetic trap. These spectra were diagnostic of the sodium atoms' energy distribution, and showed that they were a hot (by our standards), 90 millikelvin. After laser cooling (using a Doppler technique), the atoms in the trap were cooled to about 2 mK and had sufficient density ($>10^9/\text{cm}^3$) to absorb -85% of the probe laser on its passage through the sample. Members of this group are hoping to develop some novel ideas they have for cooling to microkelvin temperatures.

Professor Daniel Kleppner of the Department of Physics has been studying the onset of chaos in a small quantum system. There has been a resurgence of interest in classical dynamics stimulated by a growing appreciation for the role of nonlinear phenomena and the development of new techniques for handling nonlinear problems. The onset of disorderly motion- chaos - is of particular interest. The manifestations of chaos in quantum mechanical systems is of fundamental concern in this area. Classical motion is recognized to be a special case of quantum behavior, but quantum mechanics does not appear to have much in common with disorderly motion. Extensive numerical experiments have been carried out but experiments on real systems are lacking. Experiments have now been carried out on a real physical system: a highly excited atom in a magnetic field. Because of its relative simplicity, this system has come to be regarded as a paradigm for studying quantum and classical chaos. It has been discovered that the spectrum of the atom contains orderly progressions in a regime where the classical motion is chaotic, a finding contrary to the accepted notion of how quantum systems behave. In addition, the experimental results point the way to accurate quantum theoretical solutions to a key problem in atomic physics: the behavior of a simple system which lacks an underlying symmetry.

Professor Feld and Drs. Dasari, Michael Otterson and J. Timothy Hutton, all of the Spectroscopy Laboratory, continue their research in laser-induced nuclear orientation (LINO), which has been successfully applied in a table top experiment to measure 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 $^{85\text{m}}\text{Rb}$. The investigators also hope to use this technique to measure the angular correlation between the moments of the electron and anti-neutrino emitted in the beta-decay $^{85}\text{Kr} - ^{85\text{m}}\text{Rb}$. Professor Feld and his 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 are running an experiment using a diode laser to record to infrared spectrum of the tetrahedral molecule SO_2F_2 . This includes taking spectra at both high and low pressure to determine the energy levels of the molecule, and to determine the possibility of pumping by a CO_2 laser to develop SO_2F_2 lasing at a wavelength of approximately 18 microns.

Professor Feld and Dr. Richard P. 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.

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, Dr. Dasari and Dr. Young Park, also of the Spectroscopy Laboratory, studied laser-induced fluorescence 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)

The Electromagnetic Interaction Group (EMI) led by Professor Samuel S. C. C. Ting has successfully completed the six year construction and installation program of the L3 experiment at the European Organization for Particle Research (CERN) in Geneva, Switzerland, and was ready to participate in the first physics run of the Large Electron Positron Collider (LEP) when it was first commissioned in the summer of 1989. 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 the 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 more than 500 physicists, engineers, and graduate students from 39 different 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, Western and Eastern Europe and Asia 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 $2 \times 10^{30} \text{ c}^{-2} \text{ sec}^{-1}$. To date L3 has collected and analyzed 80,000 Z^0 particles (the carrier of the electro-weak force) and with this data sample we have been able to publish ten scientific papers including the first scientific paper from LEP. We 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. In the framework of the Standard Model, our results indicate that there are only three kinds of neutrinos in the universe (3.02 ± 0.11). We have made precise studies of the Z^0 's decay modes to search for new supersymmetric particles, etc. and set limits on the production of the Higgs boson. We have made the most precise measurements to date on the neutral current vector g_V and axial vector coupling constants and we find:

$$g_V = -0.061 \pm 0.021$$

and

$$g_A = -0.501 \pm 0.006$$
$$-0.006$$

These fundamental measurements were performed in a matter of months and are much more precise (by a factor of 10) than the previous measurements from the past twenty years of research in this area. L3 plans to continue this search for new particles and physics phenomena,

which is on the frontier of particle physics, as LEP increases its energy and luminosity in the next few years. It is expected that after several years of operation as a collider, CERN will construct a 10-20 TeV hadron hadron collider in the LEP tunnel. L3 is unique in its capacity to adapt to this modification and will be able to study phenomena in these extremely high luminosity conditions.

The experience gained at L3 is useful in designing a future detector for the Superconducting Super Collider to be built in the United States. The EMI group is leading a large international effort which has recently submitted an Expression of Interest to conduct an experiment at the SSC.

UA1 Experiment

The Proton-Antiproton Collision group is a member of the UA1 Collaboration at CERN. After the discovery of the W and Z weak bosons in 1982-1983, a large amount of data was collected to study further the properties of the W and Z bosons, to search for new quarks, new leptons, supersymmetric particles, etc. Muon data are now used to study b-quark production, B^0 \bar{B}^0 mixing, and to search for exclusive decays of B mesons involving J particle production. The group has built and is operating a large emulator farm at MIT for data analysis. They are also involved in the construction of a novel type of calorimeter using uranium and a liquid: Tetramethylpentane. More specifically this group is building a position detector for precision study of shower properties. This state of the art detector has possible applications for use in future colliders such as SSC.

The Accelerator Physics Collaboration

The Accelerator Physics Collaboration (APC) group is conducting experimental research at Fermi National Accelerator Laboratory (FNAL) in Illinois and the Gran Sasso (GSL) at L'Aquila, Italy.

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 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 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 and this subsystem is now essentially complete. The remainder of the detector is now also rapidly coming together. The accelerator group is now preparing a polarized electron beam preparatory to SLD running later this year. 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 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 and 2) Participation in the preparation of a proposal for a major detector for the Superconducting Super Collider. In this connection the group has undertaken detector R&D and plans to participate in a current hadron collider experiment at FNAL.

Lepton Quark Studies (LQS)

The LQS group is continuing its collaboration on the SLD experiment, which is to be performed with the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is participating in the commissioning phases of the Central Drift Chamber, and is also involved in the commissioning of the polarized electron beam. Tracking data from this drift chamber is to be used in conjunction with calorimeter and vertex detector information, allowing for the identification of various charged particles. This identification is crucial in the search for any new fundamental particle and in establishing the possible existence of new composite particles such as heavy-quark mesons and new gauge-like bosons. Combined with the 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. The detector is scheduled for installation into the beam line near the end of 1990 and data is expected to be taken in mid-1991.

Experimental Nuclear Physics

Relativistic Heavy-Ion Physics (HI)

The Heavy-ion Group is a large part of the E802-E859 collaboration, exploiting 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 and yielding important tests of Quantum Chromodynamics (QCD), the theory of the strong interaction. In each 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 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 three fold enhanced compared to proton induced reactions. Experiments during the coming year will help elucidate the dynamical origin of this result. To facilitate this, a selective K^+ trigger has been implemented for the Spring 1990 run. The MIT group is also improving the E802 tracking detector system as well as designing a new system that can exploit the much heavier and energetic (2700 GeV) gold beams that will become available when the AGS booster synchrotron is completed in 1991. This will provide the opportunity to reach even higher matter/energy densities. Planning for experiments at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven are underway, with construction of RHIC planned to begin during 1991.

Intermediate Energy Nuclear Physics

The principal activity in this field is located at the Bates Linear Accelerator Center, which is operated under the joint auspices of LNS and the US Department of Energy. The Laboratory serves the national community, providing intermediate energy electron and photon beams for precision studies of nuclear structure and for reaction studies aimed at a fundamental understanding of nuclear forces. The intermediate energy research programs of MIT faculty and research staff, both at Bates and at off-campus facilities, are described below; Bates developments are described in a separate contribution.

About 25 MIT graduate students were associated with the intermediate energy research program during the past year. A recent graduate, Steiner Hoibraten, was awarded the Louis Rosen prize for the best Ph.D. thesis based on research at LAMPF.

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. Results which have just become available 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.

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 helium nuclei.

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 future plans for using parity experiments at Bates to explore important fundamental problems.

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.

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 a detector 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 difficult 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.

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 is now in preparation. These are aimed at clarifying the dynamics of the short range nuclear force. A set of out-of-plane spectrometers is being developed for this purpose.

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. Following this successful measurement, we envision a continuing program of parity violation experiments. The next such experiment will be sensitive to strange quark components in the proton.

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 now being analyzed.

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 available for research 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. This is accomplished by using the SHR to manipulate the time-structure of the pulsed beam provided by the accelerator. Many of these needed detectors and the polarized beam are available.

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. There is considerable activity in this field, for example, at Argonne, Caltech, Harvard, Indiana, MIT Oak Ridge, Princeton, and Wisconsin. 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. In considering potential developments at Bates, the Nuclear Science Advisory Committee has stressed that the

"combination of internal target capability and polarized beams for addressing important new areas...will be unique in the world."

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. With the South Hall Ring experimental initiative at Bates and the major new facility at CEBAF, the American basic research community will have at its disposal unmatched capabilities built upon novel technologies.

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 destructive interference of trajectories contributing to the quark propagator. A variety of analytic approaches to QCD are being explored, ranging from classical solutions and variational calculations to a mean plaquette approximation and a truncated cumulant expansion. 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. 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 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 in formation time effects, dynamic plasma screening and final state interactions. Other studies of possible signatures include dilepton production in a non-equilibrium plasma and phi production. A flux tube model of heavy ion collisions developed previously was extended to include plasma oscillations and hadronization.

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, and a new semiclassical approximation to it reveals the origin of semiclassical "scars" observed in quantum eigenstates. 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. Stochastic techniques, which have been exploited for a variety of many-

body problems ranging from non-relativistic nuclear models with static interactions to quantum spin systems and lattice gauge theories, have been extended to circumvent the long-standing problem associated with antisymmetry for few-fermion systems in any spatial dimension.

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, with particular emphasis on the deuteron, measurement of current distributions in rotational nuclei, radiative capture, and understanding pion production near threshold. Other topics include the study of meson exchange currents, relativistic generalization of the Coulomb sum rule, and scaling in quasidelectric scattering.

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 using a hybrid bag model with external meson fields and a flux tube quark model, with the goal of exploring 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 QED in strong fields and finite chemical potential, topological structures and renormalization in field theory, quantum spin systems, and novel half-integer angular momentum solutions in quantum mechanics.

Particle Theory

This was another very active year with advances made in particle theory, field theory and also in the theoretical basis of quantum mechanics.

Interest in particle theory has focused on the structure function associated with the inelastic scattering in polarized nuclear targets. When the nuclear targets have spin one or larger, new structure functions are available for experimental study. The general theoretical basis for such investigation has been developed.

Members of the particle theory group have been working on problems in lattice field theory and the theory of strong interactions based upon QCD with members of the nuclear theory group and this work is described in the nuclear theory section.

Work on the possible role of quantum tunneling in the creating of "baby universes" has been actively pursued by theorists at many places this year. Since this problem involves an application of the as yet under-developed quantum theory of gravity, it has proved to be a very controversial subject. Theorists in our group have made an attempt to answer these questions in the most conservative way as the consequence of well-tried semi-classical methods. This attempt has led to more general investigations of the "sum over histories" formulation of quantum mechanics, in particular for quantum systems enclosed by boundaries and spin systems.

Investigation of the quantization of gravity has recently been of great interest at many places. Most have been considering first the problem in lower space dimensions, gravity in one space plus one time dimension. At MIT, as part of a general and pioneering program of the study of quantum field theory in two space plus one time dimensions, this subject has been actively pursued along with other questions associated with topology and "anomalies."

Although the theory of superstrings as a "theory of everything" is no longer as fashionable as it was a few years ago, as an example of the relativistic quantum mechanics of extended systems, it is the simplest and so far the only example which has been extensively investigated. The quantum mechanics of interacting closed strings has been one which has been most actively studied at MIT. It is the string theory which incorporates the generalization to strings of classical general relativity. During the past year at MIT, it has been proved that just as for general relativity the string theory is necessarily infinitely non-linear. The rules for this non-linear theory have been completely determined and have very interesting relationships to general mathematical theories of geometry. Conformal field theory in one-space, one-time dimensions is an off-shoot of string theory which has interested a significant number of our group. As yet the problems in this area have been mostly technical. Hopefully, in the future the technical successes will be related to the necessary physical applications to string theory.

In summary, the MIT group has been very successful in the investigation of many subtle aspects of the quantum theory of relativistic systems. The subject of particle theory has been more mathematical than in the past, partly because of the great success of the "Standard Model" in accounting for all known phenomena. Many in the group await impatiently for their experimental colleagues to uncover new phenomena which defy explanation within the context of this model.

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 1990 from the contract with the US Department of Energy (DOE) is expected to total \$29,837,000. This sum breaks down as follows: Operations costs (salaries, wages, materials, services, travel, and overhead) were \$19,256,000, of this \$6,652,000 was for experimental and theoretical high energy physics, \$10,380,000 was for intermediate nuclear energy physics for the support of the Bates Linac Facility and research program both at Bates and elsewhere, and \$1,896,000 was for nuclear structure theory, solar neutrino, and for heavy ion experiments and \$328,000 for SSC operations. Equipment costs are expected to total \$8,363,000; of this, \$6,214,000 will be for High Energy physics and \$1,372,000 for medium energy and heavy ion physics and \$777,000 for SSC equipment. A total of \$2,218,000 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 \$417,250.

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.

Richard Meserole joined the observatory staff this year as a Research Specialist.

Several upgrades to observatory facilities occurred this year. The spectrograph has been refurbished, and fans were installed in the dome of the 24-inch telescope. By reducing the thermal gradients within the dome, these have reduced the diameter of the average seeing disk from 2.2 to 1.8 arc seconds.

The major facility improvement, however, was the installation of an optical fiber data path between Wallace Observatory and Haystack Observatory under the supervision of Dr. Richard Baron. This completes the high-speed communications link to the main campus and offers the potential for observations to be carried out remotely, with complete control of the telescope and instruments. We now can put CCD images on the campus network (immediately after recording), where they are accessible to students through Project Athena workstations.

Last fall 48 students in 12S23 (Observing the Stars and Planets) and 8.287J-12.117J (Observational Techniques of Optical Astronomy) used the observatory for their laboratory work. In the spring, 30 students from 12S23 also used the observatory facilities.

Observing programs included CCD astrometric observations of Pluto stellar occultation candidate stars with the upgraded SNAPSHOT camera by Dr. Dunham, Stephen McDonald, and several observers. This season they completed a search for stars that may be occulted by Pluto and its satellite Charon for the years 1990-1995, achieving an rms astrometric accuracy of 0.3 arc seconds. Astrometric and photometric observations, in support of observing programs with the Hubble Space Telescope, were carried out by Amanda Bosh (grad), and Andrew Rivkin (Class of 1991). Observations for a senior thesis (submitted to the Department of Physics) involving CCD polarimetry were carried out by Angela Putney (Class of 1990).

JAMES L. ELLIOT

**VICE PRESIDENT, EQUAL OPPORTUNITY OFFICER,
AND SECRETARY OF THE CORPORATION**

On October 15, 1990, Charles Vest will take office as the fifteenth President of MIT, succeeding Paul Gray's presidency of the past decade. Dr. Gray will continue on as Chairman of the Corporation. But this fall marks an important transition, and completes not 10 but 19 years of Dr. Gray's extraordinary service at the helm of MIT, as Chancellor and as President.

The excitement, the intellectual ferment, and the air of uncertainty triggered by a major transition in top leadership began several months ago, with the presidential search under way, and with much attention in the community directed toward thinking about the MIT of the 1990s and of the twenty-first century.

In the spirit of this intensive look to the future, I submit in this section of my annual report not my own words, but the words of my close colleagues, the members of the Vice President's Staff Group. Our group paper, "Issues for MIT in the 1990s" (see Appendix), was written in the first half of last year and was the result of lively discussions over several drafts. Everyone in the group was an active participant in the process. The list of the members of the Vice President's Staff Group is appended to the statement.

I believe that this brief, bold, and hopeful statement about our institution is a very appropriate preface to this year's annual reports from the departments and the services for which I am responsible. It is not only a product of teamwork, but also a blend of the perspectives and the views held by the women and the men who carry managerial and staff responsibilities in the support and stewardship of MIT's human assets -- the students, the faculty, and the staff.

In past years, I have singled out the work of individual colleagues for their personal contributions to our collective goals and our plans. This year, I wish to acknowledge the effort and the quality of work of the entire leadership team in our areas.

CONSTANTINE B. SIMONIDES

APPENDIX

ISSUES FOR MIT IN THE 1990s

In response to the invitation by the Corporation Committee on the Presidency (CCOP) for viewpoints from the community, the Vice President's Staff Group* devoted some of our meeting time in the early summer and this fall to discussing what we see as the key issues facing MIT, and the next president, in the 1990s.

MIT's first five-year plan includes the following mission statement (taken from the 1983-84 Report of the President): "To provide the highest quality programs of education and research in each of those areas of study and investigation in which we have developed strength and competence, and to do so with a strong commitment to public service and to a diversity of backgrounds, interests, and points of view among the faculty, students, and staff." This mission statement is predicated on MIT's being the preeminent science-based research university in the world.

Given the special nature of MIT and its mission, and speaking from the perspective we bring from our responsibilities, we have identified the following issues and challenges as central to MIT's agenda in the next decade:

- Maintaining excellence in research
- Educating MIT students for responsible citizenship and continued growth in their professional and personal lives
- Improving MIT as a place to work
- Building stronger programmatic connections to public and world issues
- Enhancing and securing the financial foundation of MIT
- Building more effective communication and consensus in governance

Maintaining Excellence in Research

Excellence is a fragile commodity. And maintaining excellence in research is no easy task given the current climate in this country. A major obstacle facing MIT and other research universities is widespread mistrust of science and technology, growing mostly out of ignorance and misunderstanding. This attitude undermines federal support of university-based research, calls into question the motives of the university in building ties with other kinds of institutions and other countries, places limits on the nature of research (e.g., biomedical research that utilizes fetal tissue or relies on animal studies), and seeks to limit the traditional openness of communication that is vital to quality and progress in research. Scientific illiteracy or aversion also means that fewer students are interested in or prepared to pursue academic careers in science and technology, so the future quality of our faculty is jeopardized as well.

These challenges to excellence in research call for the university and its leaders not only to represent the interests of the research community at the national level, not only to speak out on the problem of scientific illiteracy, but also to encourage the faculty who do the research to consider these problems part of their responsibility as well.

* See appended list of the names and the individuals' responsibilities.

Educating MIT Students

The core requirements for an undergraduate degree at MIT place equal emphasis on the sciences and mathematics on the one hand and the humanities, arts, and social sciences on the other. While for most of our students, their major fields of study will always be emphatically centered on science and engineering, we believe that MIT should embrace the challenge to meld scientific, technological, and humanistic concerns in our educational program. Such melding is engineering at its best. Restructure of the curriculum with an aim to better integrate information and perspectives from a variety of fields is a critical step to meeting the educational needs of MIT students for the future. MIT has been a leader in the past in the development of analytical approaches to the solution of problems. It must be a leader in the future as well in developing the required new creative and integrative methods and skills necessary for working and living in a more complex, interconnected, and changing world.

An MIT education must prepare students to be constructive citizens as well as outstanding scholars and creative learners. This speaks to the importance of including languages and cultural studies in the educational program. It also speaks to the need to help students understand and develop their roles as members of a community -- not only the community of MIT, but the surrounding local, national, and international communities. Preparing students for responsible participation and contribution in a global society -- as individuals, as professionals, and as public citizens -- is a major challenge for MIT.

This challenge extends not only to what we teach and how we do it, but also to whom we teach. MIT educates its students for future leadership. In the next decade, the net addition to the labor force will be over 90 percent female and/or minority. MIT must be a leader in educating minority and women leaders.

As the student body and our community become more diverse in terms of race, gender, and nationality, MIT should pay special attention to fostering more civil and collegial behavior among its students, and among all members of the MIT community. We should take advantage of the multicultural and multiracial nature of the place to build a climate that is cooperative and productive as well as respectful of individual differences.

Improving MIT as a Place to Work

MIT is already outstanding in the diversity of individual backgrounds that make up our community. This makes it an extraordinarily interesting place to work. MIT is also an institution in transition in terms of changes in our population. This can make it a very difficult place to work when policies, procedures, informal traditions, and ways of communicating are geared to an earlier time -- a time when the needs and expectations of those who worked here were much more homogeneous. We need, as an institution, to follow the advice we gave to other American institutions in our recent study, *Made in America*: We must consider MIT people as assets to be maximized and not as resources to be used.

We need to improve our working environment by:

- recognizing and building on individual differences in backgrounds, interests and attitudes
- encouraging and rewarding more teamwork across intellectual and administrative boundaries

- improving communications, so that there is not only a greater shared understanding of policies, purposes, and concerns, but also a greater opportunity for individual voices to be heard and to be taken into account
- building support systems to moderate pressures and to help people meet the multiple and often conflicting demands of family and work
- encouraging individuals to take greater advantage of the fact that they are working in a university, with its educational, cultural, and recreational activities, both as a means of personal growth and as a way to better understand and participate in the academic culture of the place
- encouraging individuals to incorporate learning in their work, building on MIT's tradition of learning by (and while) doing, a tradition in which learning and getting things done are synergistic.

Contributions to Public and World Issues

As an international community and as an institution whose teaching and research hold worldwide influence, MIT should build on its tradition of addressing the practical concerns of the region, the country, the world, and the planet. We are especially well qualified to do so, through our recognized competence in science and technology and in our interdisciplinary approaches to solving complex problems.

In research, this means continuing to identify and work on major national and international problems, where technology and science play a central role. Such topics include industrial productivity, arms control, hazardous waste, urban infrastructures, and, perhaps the most important issue of the next decade, the global environmental crisis.

In education, this means placing greater emphasis on the social context of professional work, on languages and cultural studies, on study or internships in other kinds of institutions (in the public as well as the private sector) and in other countries -- in short, a recognition that our students are members of a global society and their education should prepare them for responsible global citizenship.

In the community of MIT, intense involvement with world issues means finding ways to build on the extraordinary multicultural population we have here. It means taking a look at how we are organized to support our international community -- students, faculty, and staff. It means continuing our insistence that scholarship and research know no national boundaries, that the quality of research and scholarship depends on open communication, that students and scholars from throughout the world are valued contributors and welcome members of this community.

Financial Strength

The wise development and expenditure of financial resources are critical to the fulfillment of MIT goals. Without a financial base equal to our needs, we will have difficulty attracting and keeping the best faculty and students. Among our peer institutions, there is extraordinary financial competition for faculty members in many fields. We are still highly dependent on research grants to support a portion of faculty salaries, a factor that places undue pressure on younger faculty members in particular.

In order to attract the best students regardless of their ability to pay, we must be able to continue our policy of need-blind admissions and of meeting the financial needs of our students.

Even as we value the support we receive from outside institutions, our research agenda is influenced by the interests of research sponsors. We need more endowment for research that is independent of external political or proprietary agenda.

In addition to increasing our endowment and other funds to support these goals, we must continue to emphasize a sound and forthright budget and planning process, and to administer the MIT budget with both creativity and restraint. To this end we must always seek ways to simplify procedures and to reduce bureaucracy.

Governance

MIT has long drawn its faculty and senior administration from its own ranks -- a tradition that has both strengths and drawbacks. Its strengths are that faculty and administration have had a closer shared understanding of the nature and purpose of MIT. This was particularly true during the period when most people at MIT came from similar backgrounds, when MIT was primarily an undergraduate institution, and when the range of fields at MIT was not as extensive as it is today.

Today, there are many forces which make it harder for people to have a shared sense of values and purpose: the faculty come from many universities; their fields are more diverse; they often identify more with their professional fields than with the institution. The student body is not only more diverse than it was, it is in some respects more different from the faculty. The daily pressures we all experience have reduced the quality of life in the university, and financial constraints make it more difficult for individual faculty as well as for the institution as a whole to embark on important new ventures.

In this environment, the governance of MIT must emphasize more effective communication. The sense and the vision some of us have that MIT must adapt and transform itself significantly in order to meet the challenges of the times and of the external environment, require not less but more and wider consultation, with a goal of building community consensus whenever possible. The reliance on a wide base of consultation and on decisions made by consensus -- in a place where the participants are of the caliber of the MIT faculty -- is an added assurance of quality for the outcome of the decisions.

The Vice President's Staff Group
December 6, 1989

VICE PRESIDENTS STAFF GROUP

Constantine B. Simonides	Vice President and Secretary of the Corporation
Michael C. Behnke	Director, Admissions
Kenneth D. Campbell	Director, News Office
Royce N. Flippin	Director, Athletics
Lois A. Graham	Assistant to the Secretary, Visiting Committees
Susan L. Kendall	Administrative Assistant to the Vice President
Kathryn W. Lombardi	Executive Assistant to the President, and Director, Public Relations Services
Nancy K. Lombardi	Administrative Officer, Office of the President
Laura B. Mersky	Associate, Analytical Studies and Planning Group; Secretary to the Faculty Policy Committee and the Committee on the Undergraduate Program
Joan F. Rice	Director, Personnel
Linda L. Rounds	Executive Director, Medical Department
Stephen D. Scarano	Assistant to the Vice President, Information Systems
Frank Urbanowski	Director, M.I.T. Press
Robert K. Weatherall	Director, Career Services and Preprofessional Advising
Arnold N. Weinberg	Director and Department Head, Medical Department
Elizabeth J. Whittaker	Associate Secretary of the Corporation
Clarence G. Williams	Special Assistant to the President, and Assistant Equal Opportunity Officer

Office of Admissions

Demographic changes continued to have a major impact on college admissions across the country. Declines in applications coupled with declines in yield resulted in many unfilled freshman classes in both the public and private sectors. The effect at MIT was a decline in applications of 5%, which was very close to the decline in the age cohort and in the number of score reports sent to colleges. Our direct competitors experienced similar or greater declines (7% at Harvard and 13% at Stanford). Of special concern was a decline of 15% in Black applicants (compared to declines of 16% at Harvard and 30% at Stanford). We were pleased however that applications from women held steady, and that the quality of the pool as measured by grades and test scores improved a bit. We also had another significant increase (from 20% of the pool to 24%) in applications from Asian Americans.

We admitted a few more students than last year because of the many uncertainties in this year's admissions cycle, but hope that the entering class will again number 1050. It appears that the class will once again be one-third women, and that we will have the second highest number (151) of under-represented minority students in MIT's history.

Another focus of attention during the year was working with members of CUAFA (Committee on Undergraduate Admissions and Financial Aid) to increase faculty involvement in the admissions process. The number of faculty readers increased from 27 to 40, and the number who evaluated more than 30 cases increased from 9 to 18. We also sponsored several meetings during which members of the faculty and admissions staff discussed sample cases. In response to the desire to recruit and enroll more academic "stars", we enlisted faculty members to call "top" admits, and we investigated ways to get names of juniors who have excelled in academic competitions.

Because of budget problems, we were unable to replace our outdated movie and to revise and reprint some publications. Fortunately, this coincided with a decrease in applications and a new system of tighter tracking of inquiries and tighter control of inventories. Consequently, we have been able to make old supplies stretch. We have also been able to save some money by shifting several projects to desk-top publishing. These included revising and producing both the undergraduate and graduate applications, producing a new college-night piece, and producing our "MIT in Review".

We worked to resolve problems in the organizational structure growing out of the functional analysis completed last year. At the same time, we tried to deal with the communication and morale problems resulting from our operation being in five different offices. Periodic all-staff breakfast and lunch meetings were scheduled both as get acquainted opportunities and as times for formal presentations on admissions issues and office functions.

With respect to travel, we have begun experiments in shifting some fall travel to the spring and in visiting minority junior high schools to encourage students to study math and aspire to college.

We began work with Administrative Systems Development to do a major revision of all files and production programs associated with the database. We also developed procedural manuals in the data entry area.

With respect to students entering with advanced placement, the number of students seeking credit increased by 9% (753 to 821), and the number receiving credit increased by 18% (599 to 708). Nine students received credit for eight or more courses and one student received credit for 15!

Once again, we received national exposure for our yearly practice of sending thank-you letters to outstanding teachers named by our admitted students. Associated Press ran a story with a photo of the director, and many papers used the story as the topic of editorials.

MICHAEL C. BEHNKE

ADMISSIONS TRENDS 1981 - 90

	<u>1981</u>	<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>Entrants from Secondary Schools</u>										
Preliminary applications	12,526	12,525	12,653	12,465	14,698	14,349	16,237	17,408	17,832	17,941
Final applications	5,922	5,921	5,959	6,055	5,747	6,213	7,372	7,437	6,698	6,426
Admissions offered	1,909	1,911	1,818	1,854	1,885	1,762	1,826	1,833	2,018	2,051
Actual registration to date	1,030	1,109	1,082	1,059	1,061	991	1,001	992	1,045	1,100*
Registrations as percent of admissions	54.0%	57.5%	61.1%	57.1%	56.2%	56.2%	54.8%	54.1%	51.2%	53.7%
Number of secondary schools represented	835	842	891	722	860	830	848	844	867	867
Percent of students from 9 northeastern states	51.9%	51.0%	50.5%	50.5%	44.7%	43.5%	39.8%	36.4%	32.5%	36.9%
<u>College Transfers</u>										
Total applications	818	1,378	1,024	1,048	909	890	870	905	658	770
Applications completed	399	425	400	304	295	317	304	349	314	377
Admissions offered	93	118	128	124	131	137	106	141	109	82
Actual registrations	76	82	91	91	101	97	80	94	82	***
Registration as percent of admissions	82%	69%	71%	73%	77%	71%	69%	69%	75%	***
<u>Graduate Students</u>										
Total applications	9,075	9,342	8,836	7,922	8,032	8,564	8,443	8,863	8,655	9,414
Admissions offered	2,926	2,920	3,007	2,223	2,467	2,457	2,243	2,101	2,549	2,384
Actual registrations	1,465	1,476	1,542	1,290	1,338	1,105	1,019	1,104	1,437	1,194**
Registration as percent of admissions	50%	51%	51%	58%	54%	49%	45%	53%	56%	50%

* Some of these will drop off over the summer.

**expected to register; actual number is not yet available (7/11/90)

***number is not available yet (7/11/90)

Educational Council

Over 1650 alumni/ae served as Educational Counselors this past year, representing MIT in all 50 states, the District of Columbia, Puerto Rico, The Virgin Islands, and 50 foreign countries. This group included 289 women and 69 minorities (47 Blacks, 6 Puerto Ricans, and 16 Mexican-Americans). The Educational Counselors represented MIT at 226 local College Fair programs; they conducted 6250 admissions interviews, and held countless conversations with prospective MIT students and with local school personnel. Of all MIT applicants, 94.3 percent (98.0 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 426 students, representing 92 different geographic areas (including 10 foreign countries), participated in this program run by the Educational Council Office.

Meetings for newly admitted students were held in 48 cities throughout the United States by Educational Council groups. Thirty-six 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 109 Central Meetings in 98 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 98 volunteers, all women professionals (from AMITA, SWE, AWIS, AWM, or other women's professional organizations) to visit 40 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 77 volunteers (39 MIT alumnae) who visited 20 high schools.

The (somewhat out of date) MIT admissions videotape continues to be a popular medium. Requests for the tape came from 47 high schools, 12 Educational Counselors, 8 applicants, and 6 MIT offices.

BONNY S. KELLERMANN

Department of Athletics

I. OVERVIEW

The 1989-90 academic year has been one of major change for our Department as we prepare for the final decade of this century and for the 21st Century just around the corner:

We have changed the fundamental structure and promotion policies of our Department faculty including discontinuation of permanent (tenured) faculty appointments and elimination of two-tiered promotion tracks. In the process we have created our own unique structure of faculty titles with full faculty benefits and the adoption of the alternative Allen/Flippin Plan.

We have changed the focus and direction of our Physical Education curriculum by introducing (in collaboration with the Medical Department) a Wellness/Health Fitness course offering with emphasis on self understanding of the long term opportunities and potential pitfalls in the achievement of a healthy, happy and fulfilling life.

We have changed and improved our relative priority position within the Campaign of the Future and the Administration agenda by establishing (With full consensus of our Athletic Visiting Committee, Athletic Board, student Athletic Association and Varsity Club) that MIT Athletic Facilities will soon be in serious trouble and dangerously uncompetitive without full implementation of the 21st Century Facilities Upgrade Package (Exhibit I).

We are changing the configuration of our Department offices by moving Associate Director for Administration and Finance, Jane Betts into a three-room "Office of the Director" arrangement where her office and mine are separated by a centralized three person support combination to be managed by Jane's new Administrative Assistant, Laura Capone, with support from my new Clerical Support Assistant and the Department Receptionist, Pier Chacon.

These changes and others of lesser significance have all been initiated with expectations of increased efficiencies and effectiveness in responding to current and future needs of our student, faculty, staff and alumni constituencies.

II. HIGHLIGHTS OF THE 1989-90 YEAR

For the fourth consecutive year our Department of Physical Education has enjoyed a record high in number of combined undergraduate, graduate student and staff course registrations. The 7,668 record number of registrations in 1989-90 is an increase of almost +18% over the past four years while the number of enrolled students has actually declined by some 250 over the same period. This achievement is a direct result of a broader, more enriching curriculum more effective and dedicated instruction, and more creative and flexible student registration publicity and procedures. The Physical Education cornerstone component can easily be taken for granted and I want to use this

opportunity to herald the exceptional leadership and dedication of Physical Education Director Gordon Kelly and Assistant Director Candy Royer as they continue to mold, enrich and energize the Physical Education graduation requirement so integral to the MIT educational philosophy of intellectual and personal development.

Under the valuable leadership of Kim O'Brion and Tim Walsh, IAP 1990 was the kick-off of the Physical Education Wellness Course offering with a followup during the 4th quarter. The two initial formats varied in length and content but were consistent in the basic offering of a health-risk appraisal, 24-hour nutrition recall, physical fitness self test, a wellness logbook and personal relationship discussions. Student evaluations were positive about the content and presentation. We are enthusiastic about the future potential for making the Wellness Equation a mandatory component of our Physical Education requirement.

In 1989-90, MIT student-athletes were honored in greater numbers than ever before in our history with 16 students selected Academic All-American; three students selected as NCAA Post Graduate Scholarship winners; our first National Football Foundation & Hall of Fame Scholar-Athlete Award; 42 different All-America selections by 20 MIT students in six sports over 18 events; a total of 24 individual and four team Straight "T" Award winners (the highest award MIT gives for athletic performance).

Two MIT coaches were selected Conference Coach-of-the-Year (Gordon Kelly, New England Division III Track & Field; Karyn Altman, New England Women's 8 Volleyball). Coach Leo Osgood was selected to coach a New England Division II-III Men's Basketball All-Star Team and Men's Lacrosse Coach Walter Alessi was selected as Assistant Coach for the prestigious North-South Collegiate All-Star Game.

Completion of three major facility improvements were capably managed by Assistant Director for Operations Rod Arthur: the removal and replacement of the chronically malfunctioning Johnson Center Ice Rink; the installation of a new air conditioning/air quality system in the heavily used year-round Class of 1974 Health Fitness Center; the purchase and installation of a new portable basketball floor to cover the hardened, injury prone synthetic floor in Rockwell Cage.

The new Constitution Athletic Conference for men's intercollegiate competition in the sports of basketball, soccer, cross-country, golf, tennis, and baseball will commence in the fall of 1990. The charter members of the Conference are MIT, Babson College, Norwich University, U.S. Coast Guard Academy, Western New England College and WPI. A full schedule of single games will take place in soccer and basketball. A single or two-day championship is scheduled for cross country, golf, tennis, and baseball in this well balanced and competitive conference.

III. FUTURE HIGH PRIORITY OBJECTIVES

Establish, fund and energize a working troika of representative from Planning, Physical Plant and Athletics to develop feasibility studies, design drawings and renderings for a feasible swimming pool and other approved project components of the 21st Century Athletics Facilities Upgrade Package. This effort is sagging and in serious danger of sinking without creative and decisive action by senior administration.

Continue to develop criteria and procedures for implementation of the Allen-Flippin Faculty Restructure Plan working closely with senior staff and the broadest possible range of other Department staff for full input and consensus.

Fully incorporate the recently developed Safety Policies and Procedures into the systematic operating procedures of all athletic facilities and programs.

Continue and increase efforts to identify, recruit and hire minority faculty/staff. Pier Chacon, a Spanish-American office assistant, and Lisa Treadway, an African-American assistant trainer have both been hired in the last few months and will enjoy their first full year at MIT in the 1990-91 academic year.

IV. PERSONNEL

Several outstanding colleagues who have contributed a great deal to our Department will be leaving for various reasons and will be difficult to replace:

Stu Nelson - Has served our Department for 38 years in various capacities at the Alumni Pool and Sailing Pavilion. He retires as Assistant Sailing Master with an extraordinary legacy of commitment to students.

Jose Rivera - Assistant Trainer on leave of absence who will not return. We were hopeful that this able and energetic young leader could have arranged to return to MIT.

Kim O'Brion - We said goodbye to this versatile and talented "dynamo" as she proceeds across the country to the University of New Mexico for graduate work in Wellness. The established Wellness Equation course offering is her legacy.

Marti Kingsley - In two short, but fully packed, years Marti brought us a New 8 Women's Soccer Championship, a wonderfully vital spirit and a special compassion for others that will leave a large void. Our loss is the gain of Bates College.

Corinne Gulas - After two exceptional years as our Head Coach of Women's Basketball (Corinne's first experience as a head coach) and many accolades including New 8 Basketball Coach of the Year, Corinne will move to the West Coast to pursue new directions with our blessing and affection. She left us a better Department with her example of energy and determination.

Ron Laham - Leaves for graduate school after an agreed one year appointment as an assistant trainer following a successful student internship with our Department. Ron is a talented professional with an excellent future. He was accepted at every graduate school to which he applied and selected the University of Virginia.

We warmly welcome back to our Department Mayrene Earle, Head Coach of Women's Crew who was on a medical leave, and Skip Whyte who was part-time last year and is promoted to Assistant Sailing Master.

EXHIBIT IMIT ATHLETICS FACILITIES UPGRADE PACKAGE

Under the wide and successful umbrella of the MIT Campaign for the Future, the goals for the Department of Athletics, Physical Education and Recreation are consistent with other important components of the Campaign to upgrade existing facilities and enhance the existing breadth and vitality of the MIT student experience.

Building from strength, MIT Athletics is in a position to make significant improvements in already existing facilities at relatively modest cost - improvements that will take us into the 21st century with minimum additional requirements. Without these improvements we could be considerably behind and in serious trouble.

These cost estimates are rough budget prices for fund raising purposes. As these projects become reality it is understood they will have to be tested through detailed schematic design work and refined cost estimates.

I. ALUMNI POOL MODERNIZATION AND EXPANSION - UP TO \$13 MILLION

The current 25 yard swimming length extended to an L-shape 50 meter complex with contiguous diving well. Use of movable bulkheads and retention of the wading pool promise multiple usage areas and maximum participation flexibility.

II. PACKAGE OF CRUCIAL ADDITION UPGRADE COMPONENTS - \$6.0 - 7.0 MILLION

- 1.) Briggs - Dupont Field House Complex - Modernization of lockers, showers, team rooms and sports medicine center. Important addition of Briggs second floor weight room/exercise center.
- 2.) Rockwell Cage - Installation of an all wood flooring system; replacement of antiquated roofing structure and heating system.
- 3.) Pierce Boat House - rearrangement of locker and shower areas to properly accommodate increased usage and shifting male-female student ratios.
- 4.) Johnson Athletic Center - Resurface and soften the second floor 200 meter track and interior tennis/all purpose surface area; Construct two (2) additional first-floor locker rooms with showers (preferably on the west side behind the hockey team benches) to accommodate the development of Women's Ice Hockey.
- 5.) Outdoor Field Complex - Complete leveling, sodding and grading to arrest the shifting and sinking of the land-fill field mass; To include soccer practice fields, rugby pitch, Steinbrenner Stadium game field area and baseball/softball arenas (including below grade baseball and softball dugouts).
- 6.) Walker Memorial Hall - Upgrade second floor athletic recreation surface and shower/locker facilities.

III. INTO THE 21ST CENTURY FACILITIES UPGRADE PACKAGE - TOTAL

\$19.0 - \$20.0 million

Career Services and Preprofessional Advising

When the president of the senior class presented the class gift at commencement, he wondered aloud whether there were any members of the class who were not going to Stanford or to Oracle Corporation. The stampede to California was not quite of that magnitude, but this was a year, certainly, when opportunities on the West Coast made up for diminished opportunities in the Northeast. While high tech companies in the Northeast suffered through hard times, the sun continued to shine over Silicon Valley and other parts of California. One out of every six companies recruiting at the Careers Office this year came from the West Coast. There were days during the winter when the office seemed to have been taken over by tanned Californians.

The response of many companies to unrelenting technical competition has been to stress quality in their hiring as much as in their products. Oracle, a software company which has made its mark in the development of relational database systems, is a good example. Since its founding in 1977 it has focussed its recruiting at a small number of schools with a reputation for having the brightest students. In 1987 it began to recruit seriously on the East Coast. Its efforts at MIT have paid off in spades - so much so that over the last four years it has recruited more MIT graduates than any other company.

Many organizations consulted us during the year on how they could best tap the talent at MIT. Some were old friends who wanted to be more effective in their recruiting. Others were new to us. A number of these were established companies who had previously drawn on schools in their local area and who had decided they needed a more varied intake. In more than one case the decision-maker was a European manager who had a European's respect for MIT as America's premier engineering school. A flock of visitors were from Japanese companies, wanting to explore the possibility of recruiting Americans to compensate for the shortage of engineering graduates in Japan. In addition, several new companies introduced themselves who were making their first foray into college recruiting.

The search for quality talent has kept a flow of companies coming to MIT in spite of generally reduced hiring needs in terms of numbers. The flow has even increased. A total of 477 employers made recruiting visits in 1989-90, more than in any year since the nineteen-sixties. They included 457 private companies and non-profit organizations, and 20 government agencies. The number of students having interviews, 1538, was a drop from the year before, but the number of interviews held, 10,400, was up a bit. The number of students was down at all degree levels - 970 undergraduates, 342 master's and engineer degree candidates, and 212 doctoral candidates. The comparable numbers last year were 1156, 420, and 250. (Other candidates having interviews this year included 9 postdocs, 4 students from Harvard, and 4 from Wellesley).

It has been our experience that less students have interviews in competitive times. One would expect the reverse to be true; more students should take advantage of the recruiting program when jobs are harder to get. But students rush for interviews when opportunities open up, and hold back when they contract. This year prospects looked cloudy in many previously popular industries - defense, computers, aerospace, automobiles, medical products, and Wall Street.

The throng of recruiters did not translate into much of a boost in salaries. For the second year in a row offers in many technical areas barely kept pace with inflation. In electrical engineering and computer science, the department with the most students reporting offers, offers to bachelors in computer science were up 4.6 percent (to \$36,100) - roughly keeping up with the Consumer Price Index - but offers to bachelors in electrical engineering were up only 2.3 percent (to \$34,300) and offers to masters rose 2.4 percent (to \$41,700). Offers to PhDs and ScDs, averaging \$55,000, did not rise at all. Better news came from chemical engineering, where offers to bachelors rose 6.4 percent (to \$35,700) and offers to masters rose 4.9 percent (to \$38,400).

It is interesting to compare these figures with the salaries reported to the Career Development Office at Sloan by master's degree candidates in management. Offers to Sloan students by manufacturing firms rose 4.4 percent - in line with offers to engineers - but offers from non-manufacturing firms rose 7.1 percent. The salary picture in engineering is discouraging if one would like to reverse the national decline in the percentage of college students choosing engineering as their major. The average offer to an MIT bachelor in electrical engineering this year was only 82 percent of what his

or her predecessor received in 1970, if one takes into account the rise in the meantime in the consumer price index. This year's master got 87 percent of what his predecessor received, and a PhD got 80 percent. Offers to masters in management, in contrast, have much more nearly maintained their value.

It has been fortunate for American science and engineering, and for American manufacturing industry, that Asia-American students have bucked the declining enrollment trend. Asian-American students have been majoring in the natural and computer sciences and engineering at more than twice the rate of European-Americans. At MIT this year Asian-Americans constituted almost a quarter of the freshman class (compared with 7 percent as recently as 1977). They and their parents have a saying that a technical education is an iron rice bowl, a means of support which will not fail you. It is an image which the American nation as a whole could take to heart. America needs the same strong rice bowl if we are to maintain our living standards in the competition with other nations.

The Asian-American students at the Institute are joined, of course, by large numbers of Asian nationals, especially at the graduate level. Both groups make active use of the office. With the assurance of a technical diploma in their hands, they are prepared to look around them at a variety of career paths. A number of Chinese students from the People's Republic came in this year to ask if there might be opportunities for them in finance, showing the same fascination with Wall Street as many other science and engineering students.

Medical School

The number of MIT applicants to medical school dropped back slightly this year to 119 (compared with 130 in 1988-89). The total number is in line with previous years, but with a trend towards students deferring their candidacy rather than applying as seniors. This year's applicant pool consisted of 76 undergraduates, 6 graduate students, and 37 alumni. Final results are not yet in but we know that all of the graduate students were accepted, 79 percent of the undergraduates, and 70 percent of the alumni. The overall acceptance rate to date is 77 percent. The applicants included 6 Black and Hispanic students (all of whom were accepted) and 44 Asian-American students.

Retirement of Phyllis Jackson

The most important human event of the year was the retirement of Phyllis Jackson in August after almost 44 years of devoted service to the office and to the Institute. Since 1971 she was manager of the recruiting program. Her job title changed over time but for the last several years it was Associate Director, Recruiting. She ran the recruiting program with wonderful efficiency, always attentive to the importance of the recruiting program to employers. She knew when to be firm but also when to be flexible. She combined in splendid fashion both efficiency and friendliness. Her office, with its always open door, was a landmark for recruiters all over the country. Many went out of their way to attend her retirement party, including one from as far away as Texas. She is greatly missed.

Anne E. Armitage, previously Assistant Director of the Institute's Integrated Studies Program, has succeeded her as manager of the recruiting program.

ROBERT K. WEATHERALL

Medical Department

Introduction

The 1989-1990 year has been busy and fruitful for the Medical Department: maintaining patient care services, providing health education activities, responding to Institute needs beyond the Department walls, teaching and advising Harvard-MIT medical students (HST) and planning for the future. The first full year of operation of the flexible option of the MIT Health Plan (Flex) was highly successful as viewed from patient satisfaction and fiscal responsibility. Members of Flex and the Traditional Health Plans used the services of the Department effectively and the results of open enrollment reflected a high degree of stability. The Inpatient Unit continues to be an invaluable resource, allowing early return of post-operative patients, the primary treatment of selected medical patients, long-term care of individuals with chronic illnesses and effective placement for selected students and health plan members for psychiatric care. The Clinical Research Center (CRC) inpatients have been ably accommodated as well, and the integration of clinical CRC activities has been achieved and tested for a full year. Underway during this year have been a number of planning activities focusing on a diverse agenda and including alcohol and substance abuse among students and a restructuring of the overall Departmental planning process. The latter involves all members of the Medical Executive Committee in an effort to decentralize planning and to involve chiefs of service directly on an ongoing basis to modify existing activities and to develop new initiatives.

I would be remiss if I did not single out the appointment of Dr. Peter Reich as Chief of Psychiatry in November 1989. Dr. Reich, as Professor of Psychiatry at Harvard Medical School, led the Psychiatry Service at Brigham and Women's Hospital and has been a consummate clinical and liaison psychiatrist in the Boston community for over twenty years. His presence at MIT has been an illuminating one in the Department and campus wide. I look forward to his continuing contributions and counsel as we face issues of alcohol and other substance abuses, stress modification, alternative modes of delivery of needed psychiatric care and our increasing geriatric population.

Medical Care Activities

Dental Service: Cynthia Stevens, D.D.S., Chief

Quality continues to be a primary goal of the Service and continuity of care issues has been addressed through improved staff communication. A major effort is underway to develop programs that are more suitable to the needs of students and also to the geriatric patients who use the service. Dental health education programs that more readily satisfy the needs of patients is another activity that is in the planning stages of the Dental Service.

The Medical Service: H. Walter Jones, Jr., M.D., Chief

During the past year monthly meetings of the primary care internists have continued allowing an opportunity for informal discussions. Among these has been the area of communication within the Department between primary care internists and subspecialists, the appropriate use of consultation services, the need to be more responsive to acute student problems, including making time available when students are freed from classroom responsibilities. In addition, we are reexamining the whole area of appointments and flexibility in this area which at times has been a source of frustration for our patients as well as for the physicians. Finally, on the suggestion of a number of primary care internists, we initiated a program of primary care rounds that are held twice monthly. This has allowed a free discussion of approaches to office practice in which younger members have the opportunity of benefiting from the experiences of more senior physicians, and senior physicians have an opportunity to hear about some newer aspects of medical care that are more familiar to junior members of the group. The primary care internists continue to provide the major experience for HST students in their first year course, Introduction to Clinical Medicine. For the second year in a row the course was rated excellent by the participating students.

Ambulatory and Off Hours Services: William A. Ruth, M.D., Coordinator

As the new Coordinator of the Ambulatory and Off Hours Services, Dr. Ruth has had the opportunity of working with Dr. Michael A. Kane, Associate Medical Director, in promoting horizontal communication and problem solving in day to day management. This has resulted in improved coordination with the nursing staff, better oversight of quality assurance parameters and the emergence of new ideas and fresh perspectives. Ambulatory visits were approximately the same as the previous year and numbered over twenty six thousand. Changes in personnel, with a number of retirements and the arrival of three new internists, made the job of the coordinator more active and with the help of H. Walter Jones, Jr., M.D., Chief of the Medical Service, the transition has been very successful. As part of the overall ambulatory care activities the primary care physicians continued to serve in a twilight coverage period from 5:00 - 7:00 p.m. each evening. This twilight coverage has continued to be effective thanks to the dedication of the individual primary care physicians and the high level of responsibility

exhibited by the fellows and senior residents who serve as the nighttime clinicians, from 7:00 p.m. - 7:00 a.m.

Inpatient and Other Medical Services: Michael A. Kane, M.D., Coordinator and Associate Medical Director

The first year of a new operational structure in the Department included the assignment of Elaine Shiang, M.D. as Coordinator for the inpatient area, in addition to her role as liaison with the CRC. The new structure of management in the inpatient area proceeded effectively with close cooperation among physicians and the inpatient nursing staff. The CRC referred all of its inpatient admissions to the Unit and benefited from the familiarity of Dr. Shiang with the activities of the overall CRC clinical program and of the Inpatient Unit.

The Department will be inspected and hopefully reaccredited by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) in the fall of 1990. Dr. Bruce Biller, in addition to his duties as Head of Quality Assurance, has again assumed the role of coordinating the Department's efforts for the preparation of the JCAHO visit. In addition Dr. Biller has replaced Dr. Ruth as Senior Physician at the satellite clinic at Lincoln Laboratory.

Ms. Janet Beyer and Ms. Maureen Dickey were asked to assume the permanent direction of the Nursing Service in November 1989 after exceeding all expectations in their interim co-management of the Nursing Service. During this past year Ms. Theresa E. Connolly was appointed Head Nurse of the Inpatient Unit with Ms. Margaret P. Sullivan as the Assistant Head Nurse. In addition we have begun to offer a variety of other services within the Inpatient Unit including total parenteral nutrition and we are studying the availability of blood transfusions that can be offered on a compassionate basis without patients having to be transported to other neighboring hospitals. Dr. Carol Tereszkievicz became the overall coordination of our teaching programs this year. The Medical Department is a training site for primary care residents from Mount Auburn Hospital. She has initiated primary care rounds for residents, their preceptors and other interested persons. Dr. Tereszkievicz' efforts in this area have been singularly outstanding and in addition she has had the major responsibility for the medical engineering course, Introduction to the Clinic.

Obstetrics and Gynecology Service: Charles F. Eades, M.D., Chief

The Service continues to be busy with increased numbers of patients seen on an ambulatory basis and nearly two hundred deliveries at the Brigham and Women's Hospital. Many other services were rendered by the physicians and nurse practitioners of the Service during this past year. Our infertility program burgeoned this year with seventy two new patients between November 1989 and the end of May 1990. This program has been ably overseen by Dr. Annie S. Liao and clinician nurse practitioner, Ms. Karen Halvorsen. Educational activities included precepting of residents as well as teaching of childbirth preparation to prospective mothers during six series, consisting of seven evening sessions, ably coordinated by Ms. Halvorsen. Because of the increased clinical load and the presence of a number of part time doctors, we have enhanced our communication by monthly meetings and by efforts coordinating clinic scheduling, on call physician notification, triaging, follow up of laboratory work, etc. This could not have been accomplished without the overall direction of the coordinator, Ms. Dolores Vidal, nurse practitioner.

Pediatric Service: Barbara L. O'Pray, M.D., Chief

The addition of another half time pediatrician, Dr. Barbara Katz, has allowed us to keep up with the increase in the number of patients seeking care during routine appointment time, and also to extend our clinical hours three mornings a week by beginning at 8:00 a.m. The Pediatric Service provides a variety of other services outside of the traditional primary pediatric care in the Department. This includes consultations, care for employees' and students' children, as well as the Lincoln Laboratory Children's Center. In summer, emergency service care is provided for the MIT day camp. Each physician on the Pediatric Service covers hospitalized patients at Children's Hospital and rounds on all newborns as well. Our pediatricians teach medical students at Children's Hospital, Brigham and Women's Hospital and in the HST Introduction to Clinical Medicine course.

Psychiatric Service: Peter Reich, M.D., Chief

Visits to the Psychiatric Service increased 8.2 per cent during this past year, evenly divided among undergraduates and Health Plan members. Referrals for therapy outside MIT dropped significantly by over 20 per cent in both the Health Plan and student groups. The number of days that individuals were cared for in the Inpatient Unit decreased from 185 to 162 days this year. Hospitalization elsewhere, excluding substance abuse, remained about the same between last year and this year. The Psychiatric Service went through a leadership transition with Acting Chief, Joseph Brenner, M.D., stepping down in November when Dr. Reich became Chief of the Service. Dr. Brenner had done a superb job of leading the Service after Dr. Kahne's retirement and has been an enormous help to Dr. Reich during the transitional period. During the year a major decision was reached to expand our training programs. On July 1, 1990 three postdoctoral psychologist trainees and two postgraduate year IV psychiatric residents will receive part of their training in the Psychiatric Service. This has been a stimulus to the entire

Service and was arrived at by unanimous agreement of the staff. It is hoped and anticipated that the increase in clinical time provided by new staff members and by trainees will enable the Service to carry more patients in therapy and will expand the low barrier walk in component of the program. It is also anticipated that we will have increasing involvement in educational, preventive and academic activities of the Department, the MIT community, HST, and other areas that relate to the MIT campus.

Social Work Service: Ronald C. Fleming, LICSW, Chief

Clinically the Social Work Service has provided a spectrum of care to nearly five hundred individuals in the MIT community and this has involved slightly less than four thousand visits. Additionally, the Service has involved itself in a number of outreach activities including assistance in developing a survey on work and the family and involvement in issues of caring for aging parents and supportive services to working parents. We are involved in the development of "drug free" workplace and campus through a variety of interfaces including the personal assistance program. The staff has contributed to the Institute's goal of maintaining and encouraging diversity by supporting members of the minority community, and providing a variety of other forms of assistance both indirect and direct to individuals and other groups on the campus. All members of the staff received special training in areas of concern for the '90's including AIDS and the sexually abused. Staff members have also continued their roles as educators and facilitators of early intervention, especially through outreach efforts in the personal assistance program. On campus the Social Work Service has been involved in groups like Alcoholics Anonymous, Alanon and Co-Dependents Anonymous, all contributing to the well being of members of the MIT community.

Surgical Services: Stephen J. Healey, M.D., Chief

Changes in the spectrum in the activities of the Surgical Services have led to a reorganization of the General Surgical Services and the Orthopedic Service with a contraction of physicians on each of these services. Neurosurgical care for back and central nervous system problems will now be referred to the Neurosurgical Service at Massachusetts General Hospital. Some of the activities of the Surgical Service, like skin biopsies and endoscopies, have been transferred to the Dermatology Service and the Gastrointestinal Subspecialty Service respectively. An expansion of our urology clinical activities has resulted in the addition of Dr. Roderick Crocker joining Dr. George Reservitz. Inpatient activities have remained active including caring for patients with central line access and on hyperalimentation. Efforts have likewise continued to expedite the early transfer of all surgical patients to the Inpatient Unit for post-operative care. Our impression is that the inception of in-house mammography studies, with a state of the art machine, has resulted in earlier discovery of highly curable breast tumors in a number of patients. This easy access to mammography in the Department has led to better patient compliance overall for breast cancer screening.

Nursing Service: Janet V. Beyer, R.N.,C., Maureen Dickey, R.N., Co-Chiefs

In November 1989 the Co-Supervisors of the Nursing Service were made Co-Chiefs. This necessitated a variety of personnel changes and adjustments in the ambulatory, in-patient, Lincoln Laboratory and CRC areas. The nursing contribution to the Off Hours Clinic continues to be stable in spite of increased demand. Continuing education has remained an important focus in biannual CPR programs for all nursing personnel and encouragement for participation in outside continuing education presentations. In addition a variety of in-house programs have been offered during this past year including emergency equipment in-service, better back, diabetes, adolescent drug, laughter and healing programs, the First Annual Gould Memorial Lecture, update on infertility and treatment modalities for alcoholism.

Other Departmental Activities

Clinical Research Center (CRC): Naomi K. Fukagawa, M.D., Coordinator

Incorporation of the clinical activities of the CRC into the Medical Department has been successfully completed during this year. All physicians with CRC appointments are also members of the Medical Department and members of the CRC staff participate on various committees of the Medical Department. Both outpatient and inpatient research activities have increased and continue to run smoothly with respect to Medical Department activities. It is anticipated that the CRC will become an important source for career development of the medical staff and potentially for fellowship training.

Environmental Medical Service (EMS): Alan M. Ducatman, M.D., Chief

This year was again without significant environmental health incidents or related regulatory problems. Progress can be reported in previously identified goals including the almost fully computerized activities for EMS, health/physics information, asbestos survey data, and fume hood inspection information. The shift from primarily air to bulk sampling in the asbestos program reflects a change from reactive to proactive cooperation and will save both time and money in performing renovations. A campus wide blood borne pathogen training program is in place and food service employees are receiving sanitation trainings. New programs for non-ionizing radiation protection, including survey of exposure potential, are in place.

EMS presented an EPA funded laboratory waste management course attended by two hundred and fifty from universities and other educational institutions, businesses and regulatory agencies. This successful course exceeded attendance and expectations. We are in the process of preparing a major document to help departments meet the requirements of the new OSHA laboratory standard and are cooperating with the Safety Office and Office of Purchasing of Laboratory Supplies in tracking and reducing the use of hazardous chemicals of regulatory concern. The nuclear reactor is becoming more active requiring our attention to new EPA and NRC regulations.

Health Education Service (HES): Janet H. Van Ness, M.S.P.H., Coordinator

Program participation increased eleven per cent over last year in a variety of workshops, presentations, Independent Activities Period (IAP) programs and other activities. In addition the Service was catalytic for the organization of several educational and support groups which have developed their own missions to promote awareness on specific health issues. Among significant core programs developed this year were, "Talking to Your Teenager" and an American Red Cross certified CPR course for parents of infants and small children. The third annual Successful Aging Seminar, co-sponsored by the Medical Department and the MIT Honorary Matrons, organized by Ms. Katherine Stratton, was once again successful attracting over one hundred and sixty people. This year's Seminar covered health insurance for long term care, placement of orthopedic prostheses and issues of physiotherapy and mobility following orthopedic procedures. There were fifty seven health promotion workshops offered during January IAP attended by over eleven hundred members of the MIT community. Additional programs included nursing mothers support group and presentations on backache, physical fitness, parenting, stress and AIDS. The CRC invited the HES to participate in a study of the effect of two drugs in reducing relapse in smoking cessation efforts. A two year grant from the U.S. Department of Education for Alcohol and Drug Education has allowed us to focus more attention on substance abuse issues among MIT undergraduates, using our Student Health promotion project "Staying Healthy at MIT" as the vehicle for implementing this activity. A Student Health Resource Center has opened in the Stratton Student Center. A peer education group has been developed and educational sessions on substance use and abuse have begun to interest living groups and social organizations on campus. A drug and alcohol use and attitudes survey of twenty five percent of the undergraduate student body was completed in May and the analysis of this survey will help to further develop education programs relating to substance abuse. The HES has continued to advise two peer education groups, Women's Health Education Network (WHEN) and AIDS Response at MIT (ARMIT). ARMIT was the recipient of two awards for service, the Institute's Compton Award and Honorable Mention in a nationwide campus leadership awards program. ARMIT's collaborative involvement with the Medical Department, the MIT Museum and the List Visual Arts Center, in planning the Institute's December 1st World AIDS Day, was highlighted by the observance of a poster session at the Sixth International Conference on AIDS in San Francisco.

Lincoln Laboratory Medical Clinic: Bruce J. Biller, M.D., Coordinator

The Medical Clinic at Lincoln Laboratory has been the focus of a number of physical improvements and administrative changes during this past year as we prepare the Clinic for scrutiny by the JCAHO as part of its overall survey of the Medical Department. A variety of presentations were given during open enrollment to educate individuals at Lincoln Laboratory about the facilities of the Medical Department. In addition we reviewed policies and procedures for emergency care, performed a patient satisfaction survey, and developed new quality assurance monitors for the Lincoln Laboratory Clinic. There have been a number of changes in staffing that have streamlined the working relationships in the Clinic and planning is underway to place the future of the Lincoln Laboratory Clinic as well as the Medical Department's activities at Lincoln Laboratory into a more responsive framework.

Student Health Services (SHS): Mark A. Goldstein, M.D., Chief

We continue to make efforts to enhance communications between the Medical Department, other departments and incoming students. These administrative efforts have resulted in the strengthening of relations with graduate students and in the promotion of far greater compliance with the Medical Department requirements for updating medical records and appropriate immunization information. Departments are beginning to appreciate the Medical Department's needs and to assist us in helping graduate and undergraduate students.

A unique effort was initiated to raise the consciousness of the student community to AIDS issues. A student art contest and exhibition entitled "Changes in the Age of AIDS" drew many exciting and creative entries and the winner of the MIT contest was the only piece of art that was displayed at the Sixth International Conference on AIDS in San Francisco. The contest enabled the Department to strengthen its ties with students, student groups and with other departments. ARMIT, which was a co-author of the presentation, won both institutional and national awards.

Foreign student health issues continue to be a major problem on a campus that has such a large representation from the international community. Dr. Goldstein was selected along with Dr. Melena Levak of the Student Affairs Office to study

issues of international students at a national invitational workshop at the University of California. As a result of that workshop initiatives have been undertaken to improve delivery of health services to our many international students. A research proposal on AIDS attitudes and information among international students is under review for funding as a collaborative effort between the Office of the Dean of Student Affairs and the Medical Department. We continue to make every effort to improve our visibility among students and also to increase our awareness of what the students perceive as problems with dealing with the Medical Department.

Teaching and Clinical Education: Carol A. Tereszkiwicz, M.D., Coordinator

The Mount Auburn Hospital primary care internal medicine residency program at MIT was improved during this year by the presence of two residents sharing a full time position. In addition to the residents other primary care physicians in the Department participated in clinical conferences, both as coordinators of a conference or as part of the group being educated. Each of the primary care residents is precepted by a senior member of the Medical Department and a variety of areas beyond primary care have been included, such as office gynecology which was ably supervised by Dr. Annie S. Liao of the Ob/Gyn Service. The medical engineering/medical physics Introduction to Medicine course was given this year for six students and was rated very highly by them. The course was organized by Dr. Tereszkiwicz and clinical teaching supervision was provided for members of the Medical Department.

Clinical Operations and Planning: J. Christian Kryder, M.D., Assistant Medical Director

Activities over the past year have been divided among subspecialty and ancillary operations, the management of MIT Health Plan (MITHP) patients in outside hospitals, and broader departmental planning. In the area of subspecialty and ancillary services, we have made significant progress in improving timely communication for consultative services with subspecialists at MIT and in the community at large. Subspecialists have been attending regular monthly staff meetings. The Orthopedic Surgical Service has had a major restructuring joining all other specialty services, except Dermatology, as a referral service. The Gastroenterology Service has seen a steady increase in the volume of flexible sigmoidoscopies performed in-house. Neurology referrals have increased slightly and we now have engaged a new resource for neurosurgical consultation and neurosurgical therapy at the Massachusetts General Hospital. The Nutrition Service had an increasing demand and we are currently reviewing additional services that might be provided by the Nutrition Service, including cholesterol monitoring, patient guidelines and modified dietary programs for overweight individuals. The Podiatry Service has continued to grow in popularity and now Dr. Bruce T. Wood supervises a resident in podiatry from the Massachusetts General Hospital. This has led to a substantial increase in number of patients to be seen. Mammography screening has continued to expand under the able direction of our radiology group and with state of the art mammography equipment. Health Screening Services have been reorganized under the leadership of new manager, Ms. Julie S. Mitchell. Emergency Services continue to be enhanced. We are revising emergency assistance protocols and have begun mock drills and codes in the Department. Finally, agreement has been reached with campus police to set up a two level ambulance response. Critically ill patients will be transferred by paramedics providing Advanced Cardiac Life Support (ACLS) level care directly to neighboring hospitals.

We manage a number of medical and surgical admissions to outside hospitals each year. In all cases the standard has been to insure the timely care of the patient in the outside hospital followed by transmission of medical data relative to patients' acute and continuing needs on referral back to the Medical Department. A substantial and increasing number of these patients are transferred to the MIT Inpatient Unit for continuing and convalescent care. In addition to admission to outside hospitals most requests for approval for emergency services are reviewed so that appropriate medical problems can be triaged back to our Department.

We have restructured the planning process to involve all members of the Executive Committee of the Department. This major initiative began with a retreat in April 1990 attended by all members of the Medical Executive Committee. The objective of the change is to decentralize planning wherever possible and to involve Chiefs of Service in a direct and ongoing basis in the planning affairs of the Department. On the basis of the retreat and meetings held thereafter four Medical Executive Committee Task Forces have been designated and have begun activities. The four areas include MIT Student Health, the Future of the MIT Inpatient Unit, Career Development and Enhancement, and Referral Resources of the Medical Department. Another area of activity has been the continued pursuit of joint ventures with Harvard University Health Services, particularly in areas of subspecialty coverage and shared ancillary services. A major area for planning is the medical care for senior and retired populations at MIT. Preliminary work indicates that it may be feasible for the MIT Medical Department to offer a type of Medigap Insurance Plan. The elderly population is loyal to the Medical Department and is served well but it is obvious that the needs of these individuals are complex and require a special effort so that we can serve this valued group of senior citizens in a more thoughtful and creative way, consistent with the benefit structure of MIT.

Personnel Changes

The following changes occurred for Administrative and Academic Staff during the period June 1, 1989 through May 31, 1990:

APPOINTMENTS

Bethany R. Block	Physician
Kevin M. Coghlan	Industrial Hygiene Technologist
Roderick M. Crocker	Physician
Stephen Falkenberry	Obstetrician/Gynecologist
Leigh M. Firn	Physician
Margaret L. Forsyth	Physician
Barbara Frank	Administrative Assistant to the Medical Director
Cyril Gaum	Dentist
Elizabeth A. Gilman	Assistant Biohazard Assessment Officer
Lili A. Gottfried	Psychiatrist
Barbara J. Katz	Pediatrician
Patricia J. Kittredge	Inpatient Nurse
Kenneth P. Martin	Industrial Hygienist
Jeanne McKiernan	Inpatient Nurse
Barry Mendes	Industrial Hygiene Technologist
Aaron Menzin	Psychiatrist
Julie S. Mitchell	Operations Analyst
Linda Salsa Olson	Coordinator, Claims and Members Service
Peter Reich	Chief, Psychiatry Service
Walter T. Rymzo	Physician
Elizabeth Stewart	Obstetrician/Gynecologist
Susan L. Warren	Postdoctoral Fellow, Psychiatry
Grace L. Wong	Nutritionist

RESIGNATIONS/RETIREMENTS/CHANGES

Nancy A. Barbour	Industrial Hygiene Technologist
Mary R. Connolly	Nurse Practitioner
Mary Lou Every	Nutritionist
Fruma W. Ginsburgh	Obstetrician/Gynecologist (Retired)
Donna Kent-Spencer	Audiologist
Jeanne M. McKiernan	Inpatient Nurse
Adelaide M. Morin	Administrative Assistant (Retired)
Barbara K. Prazak	Physician
Robert Russell	Inpatient Nurse
Leonard Wolsky	Physician
Norma Stark	Inpatient Nurse (Deceased)
Janet V. Beyer	Co-Director of Nursing Services
Maureen Dickey	Co-Director of Nursing Services
Theresa E. Connolly	Assistant Head Nurse
Margaret P. Sullivan	Assistant Head Nurse

Concluding Comment

The Medical Department continues to mature. There is a growing sense of responsibility, desire and willingness to participate by individuals at every level to carry out the missions of the Department in caring for the community. The students remain a high priority, balanced by a strong desire to provide broader services for the elderly members of the MIT family. We look forward to the recommendation of the four task forces, to our relationships with outside providers and to the results of vigilant fiscal planning and cost containment measures that do not impinge on quality or in the availability of care. Our

contributions to the MIT community surface in other ways too. The leadership of Dr. John M. Moses, as Chairman of the Animal Care Committee and of Dr. H. Walter Jones, Jr., Chairman of the Committee on the Use of Humans as Experimental Subjects, reflects our interest in MIT beyond the Medical Department boundaries. Through educational efforts in conferences, rounds, direct supervision of medical students, residents, fellows and trainees, we hope to continue to grow professionally and to provide up to date care to this community. I want to acknowledge the invaluable contributions to the Department of Ms. Linda L. Rounds, Executive Director, Dr. Michael A. Kane, Associate Medical Director and Dr. J. Christian Kryder, Assistant Medical Director.

ARNOLD N. WEINBERG, M.D.

Fiscal Year 1990 witnessed a rapid growth in the number of titles we published in each of our core programs. Overall sales, however, increased a modest six percent, and we experienced a \$500,000 shortfall in our sales forecast. Domestic sales growth from FY89 was essentially flat, foreign sales were up 17 percent and accounted for about 32 percent of total sales. The Journals Division results were on target, producing a net from operations of \$83,000, a significant improvement over last year.

The shortfall produced a deficit from overall operations of \$295,000, which was charged against our general reserve. In addition, the Press retired the remaining portion of its accumulated deficit of \$200,000, which has been carried on the balance sheet since FY83.

There were several reasons for the sales shortfall. Most significant were late titles: there was about \$300,000 of booked backorder sales for titles which were not released by the end of the fiscal year; there was also a significant increase in returns from booksellers (up 20 percent over the previous year with returns at a rate of 30 percent of sales in the last quarter, the same level experienced by our sister presses). Our operating deficit was also contributed to by significant writedown, primarily on import titles. Another contributing factor, also a common experience among other university presses, was a general delay in order placement by bookstores for textbook adoptions, which usually come in the last two weeks of June. There is a general sense of caution among bookstores, hence they're returning books as a substitute for reducing their accounts receivable balances, delaying textbook orders, and buying cautiously during the current year.

The outlook for FY91 is cautiously optimistic. We have a large and promising new list, and the experience of 1990 has generated a certain spirit of alertness to opportunities for maximizing sales and squeezing budgets.

Among the core programs performing exceedingly well, were economics (up 30 percent) and cognitive and brain sciences (up 14 percent). Sales in architecture and design, which includes arts and humanities were down over the previous year, primarily because of late publications. Sales in computer sciences were up modestly, and sales in philosophy and linguistics were flat over FY90.

We published 205 titles last year; 171 original publications, and 34 paperbacks reprinted from our own hardcover backlist, an increase of 31 percent. Overall, unit sales improved modestly to 615,000 copies.

Bestsellers from the Fiscal 1990 list included:

Klivington
Starr
Frieden & Sagalyn
Strong
Posner
Adams

Science of Mind
Southern Comfort
Downtown Inc.
The Copyright Book
Foundations of Cognitive Science
Beginning to Read

Wollen	<u>On the Passage of a Few People...</u>
Caudill & Butler	<u>Naturally Intelligent Systems</u>
Buck-Morss	<u>The Dialectics of Seeing</u>
Hollier	<u>Against Architecture</u>

MIT authors:

Blanchard & Fischer	<u>NBER Macroeconomics Annual 1989</u>
Bolton	<u>The Contest of Meaning</u>
Cormen et al.	<u>An Introduction to Algorithms</u>
Eisenberg	<u>Programming in Scheme</u>
Frieden & Sagalyn	<u>Downtown Inc.</u>
Horn & Brooks	<u>Shape from Shading</u>
Krugman	<u>Rethinking International Trade</u>
Modigliani	<u>Collected Papers, vols. 4 and 5</u>
Osherson	<u>An Invitation to Cognitive Science</u>
Temin	<u>Lessons from the Great Depression</u>
Ward & Halstead	<u>Computation Structures</u>
Williams	<u>Notes on the Underground</u>
Winston & Shellard	<u>Artificial Intelligence at MIT</u>

Among the noteworthy books by non-MIT people from our scholarly and professional program were:

Adams	<u>Beginning to Read</u>
Baumol et al.	<u>Productivity and American Leadership</u>
Brady	<u>Robotics Science</u>
Carroll	<u>The Nurnberg Funnel</u>
Churchland	<u>A Neurocomputational Perspective</u>
Cowell	<u>Cheating the Government</u>
Earman	<u>World Enough and Space-Time</u>
Jackson	<u>The World Trading System</u>
Kolb & Tees	<u>The Cerebral Cortex of the Rat</u>
Neale	<u>Descriptions</u>
Pollock	<u>How to Build a Person</u>
Posner	<u>The Foundations of Cognitive Science</u>
Rizzi	<u>Relativized Minimality</u>
Shiller	<u>Market Volatility</u>
Stigum	<u>Toward a Formal Science of Economics</u>
Truxal	<u>The Age of Electronic Messages</u>
Van Lehn	<u>Mind Bugs</u>
Wollen	<u>On the Passage of a Few People...</u>
Yoshikawa	<u>Foundations of Robotics</u>

New hardcover books for trade and general audiences included:

Buck-Morss	<u>The Dialectics of Seeing</u>
Caudill & Butler	<u>Naturally Intelligent Systems</u>
Connah	<u>Writing Architecture</u>

Derian	<u>America's Struggle for Leadership...</u>
Forester & Morrison	<u>Computer Ethics</u>
Graubard	<u>Living with AIDS</u>
Habermas	<u>The New Conservatism</u>
Hollier	<u>Against Architecture</u>
Jarzombek	<u>On Leon Baptista Alberti</u>
Klivington	<u>The Science of Mind</u>
Küppers	<u>Information and the Origin of Life</u>
Le Dantec & Le Dantec	<u>Reading the French Garden</u>
Mark	<u>Light, Wind, and Structure</u>
Pacey	<u>Technology in World Civilization</u>
Starr	<u>Southern Comfort</u>
Tafari	<u>Venice and the Renaissance</u>
Vidler	<u>Claude-Nicolas Ledoux</u>

Books published primarily as texts included:

Benninga	<u>Numerical Techniques in Finance</u>
Biermann	<u>Great Ideas in Computer Science</u>
Chierchia & McConnell-Ginet	<u>Meaning and Grammar</u>
Finke	<u>Principles of Mental Imagery</u>
Gerrard	<u>Mountain Environments</u>
Harvey	<u>The Econometric Analysis of Time Series</u>
Lewis	<u>Approaching Precalculus Mathematics Discretely</u>
Sharples	<u>Computers and Thought</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); Frank Satlow (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 Dick Woelflein, production manager, the editorial and production departments continued to add quality to our publications. The design department, under Diane Jaroch, 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 Art Director's Show of Boston, Print Magazine, The American Institute of Graphic Arts, and International Design Magazine.

COMPARATIVE OPERATING RESULTS (in thousands)

	<u>Fiscal Year</u> <u>1990</u>	<u>Fiscal Year</u> <u>1989</u> <u>Actual</u>	<u>Fiscal Year</u> <u>1988</u> <u>Actual</u>
Total Net Book Sales	\$ 10,206	\$ 9,706	\$ 8,830
Cost of Sales	<u>4,578</u>	<u>4,242</u>	
Gross Margin on Sales	5,628	5,464	5,109
Other Pub. Income	164	126	167
Bookstore Net	<u>110</u>	<u>95</u>	<u>90</u>
Total Income	5,902	5,685	5,366
Operating Expense	<u>6,280</u>	<u>5,814</u>	<u>5,292</u>
Net Books Division	(378)	(129)	74
Journals Net	<u>83</u>	<u>42</u>	<u>4</u>
	(295)	(87)	78

Faculty serving on The MIT Press editorial board in 1989-1990 were Professors Harold Abelson, Stanford Anderson, Penny Chisholm, John P. Longwell, Peter Diamond, Albert Meyer, Daniel Osherson, Merritt Roe Smith, Robert Solow and Robert Silbey. 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 Robert L. Solow, Professor in the Department of Economics and Chairman of The MIT Press Editorial Board. Robert M. Solow, Chairman of The MIT Press Editorial Board and Frank Urbanowski, Director of The MIT Press, are ex-officio members and Constantine Simonides, Vice President in the Office of the President, 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

<u>Customer Type</u>	<u>Fiscal Year 1988</u>	<u>Fiscal Year 1989</u> (in thousands)	<u>Fiscal Year 1990</u>
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% in FY90.

INTERNATIONAL SALES

A significant increase in title output and burgeoning economies in many foreign countries contributed to a very strong year in international sales. Reorganization of the marketing program in Australia and New Zealand was completed in the last half of FY89, and this produced a 32 percent increase in sales to these countries in FY90. Canadian sales, bolstered by very strong textbook adoptions, increased by over 24 percent. Japan and Continental Europe, with their strong economies and a demand for books in a wide variety of subject areas, bought more MIT Press books because there were many more new titles to buy. The results were a 22 percent revenue increase in Japan and a 19 percent increase in Continental Europe.

	<u>International Book Sales FY 1988 - 1990</u>		
	<u>Fiscal Year 1990</u>	<u>Fiscal Year 1989</u>	<u>Fiscal Year 1988</u>
Australasia	\$ 161,500	\$ 122,300	\$ 83,800
Canada	509,600	409,500	356,100
Japan	551,300	450,000	428,900
UK/Continent	1,502,500	1,365,700	1,361,000
Other	<u>437,600</u>	<u>352,500</u>	<u>438,000</u>
TOTAL EXPORT	3,162,500	2,700,000	2,667,100
percent of total	31.8	28.7	31.2

SUBSIDIARY RIGHTS

The core of the subsidiary rights program continues to be translation rights sales. The increase in translation income this past year (FY90) (41 percent) indicates a growing interest in the

purchase of foreign rights abroad. Our strongest lists in this regard continue to be cognitive and computer science, although we are also becoming known for our emerging list in philosophy/aesthetics.

This year's permissions income increased significantly, both because of greater efficiency in handling permission inquiries and billing, and due to the sale of paperback rights to three of our titles. The most significant of these was the sale of Dertouzos et al Made in America to Harper and Row, whose trade paperback edition is scheduled for publication this fall. Also included in this category are sales of reprint rights to the Far East. This is an area we are exploring cautiously, but one which is expected to grow. We have recently located an agent based in Taiwan who will be able to handle transactions involving Chinese language translations of our books as well as English language reprints in this difficult and changing market.

As expected, subsidiary rights income from sales to book clubs decreased. The configuration of the major book clubs to which we sell has changed drastically this past year, with the spin-off of Macmillan Book Clubs, now Newbridge Communications, Inc. Since it is not clear what Newbridge's editorial and financial plans are for the future, we project no growth in this area for the time being. TAB Book Clubs, which emerged as a competitor of Macmillan's Library of Information Science Book Club, was recently purchased by McGraw-Hill Book Clubs. Historically, McGraw-Hill Book Clubs buys very few titles from other publishers. Therefore, we expect few sales to TAB.

Total subsidiary rights income increased by 22 percent in FY90.

	<u>Subsidiary Rights Income FY87 - FY89</u>		
	<u>Fiscal Year 1990</u>	<u>Fiscal Year 1989</u>	<u>Fiscal Year</u>
<u>1988</u>			
Translation Rights	\$ 148,131	\$ 98,509	\$ 87,449
Permissions (incl pb rights)	65,724	29,499	15,093
Reprint Rights	25,986	61,281	46,046
AudioVisual	<u>200</u>	<u>1,400</u>	<u>8,726</u>
	240,041	197,179	168,374

PROMOTION, PUBLICITY, AND DIRECT MARKETING

Text sales continue to increase, topping \$2 million again this year. And, best-sellers continue to be the economic texts by JeanTirole/The Theory of Industrial Organization, and Oliver Blanchard/Lectures in Macroeconomics, and the Parallel Distributed Processing volumes by Rumelhart and McClelland. There was also a flurry of adoptions for The MIT Commission Report by Dertouzos et al, Made in America. We shipped fewer books overall (unit sales were down by 0.31percent) and text returns were higher than usual.

MIT Press books were mentioned or featured in in several thousand reviews and listings. Made in America garnered the most attention from review sources and from the wire services. There were also feature reviews in the New York Time Book Review of books by MIT's Rosalind Williams (Notes from Underground); Bernie Frieden and Lynn Sagalyn

(Downtown Inc.), for Susan Buck-Morse's The Dialectics of Seeing, and for Fred Starr's Southern Comfort.

Advertisements for books appeared in 333 trade and scholarly journals and magazines, compared with 294 last year, an increase of 13 percent, which reflects the continued growth of the computer science and neuroscience programs as well as special projects in materials science and education.

The net contribution to sales from the Exhibits Program was down slightly from FY89 (four percent), but again exceeded \$100,000, for a net contribution of \$115,480, most of which was generated by our attendance with a booth at 36 meetings. The increase in costs, however, was half that of the year before. To keep costs down, our Exhibits Manager made a special effort to increase the number of free meetings that the Press attended. These conferences generated \$21,000 more than last year. Sales were particularly strong at the International Joint Conference for Artificial Intelligence (IJCAI), Society for Neuroscience, Allied Social Sciences, College Art Association, and Society for Architectural Historians meetings.

Direct mail traceable sales were \$509,150, down slightly (nine percent) from FY89. This decrease can be attributed in large part to books that were announced for the Fall and Spring but did not ship. The economics catalogs produced the highest income with \$92,627 in sales, followed by cognitive science, computer science, and art and architecture.

JOURNALS

The past year has been one of consolidation and continued expansion of the journals program. Gross sales were \$2.4 million, a nine percent increase over last year. \$25,700 was added to the reserve account. New total reserves at year end were \$999,300. Journals produced a net surplus of \$83,600, up from last year's surplus of \$42,000.

One journal -- Materials and Processing Report -- left the program after being purchased up by another publisher. The new journals begun in FY89 (Neural Computation and Journal of Cognitive Neuroscience) ended their first volume years ahead of projections in both circulation and income. The two existing journals acquired in 1989 (Design Issues and Computational Linguistics) improved greatly in 1990 because of successful promotion and cost control measures.

One journal was added to the program in 1990 -- The Ecologist. We entered into a distribution agreement with the British publisher, Ecosystems, to handle subscriptions in North America. The circulation increased from 600 to almost 1400 in six months.

There are now twenty-one journals in the program. The others are: Assemblage, Computer Music Journal, Design Quarterly, The Drama Review, Journal of Interdisciplinary History, International Organization, International Security, Linguistic Inquiry, Materials and Processing Report, Mimar, NBER Macroeconomics Annual, October, The 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.

Personnel Office

On July 1, 1989 the Retirement Plan for staff members and the Retirement Plan for Employees were merged to become the MIT Retirement Plan. The Independent Union of Plant Protection Employees at the Lincoln Laboratory asked to join the Plan on the July 1 date. All other employees represented by unions, and whose participation was subject to collective bargaining, joined the Plan on January 1, 1990 after long, protracted negotiations.

An important staffing change occurred with the retirement of James J. Fandel whose career at MIT spanned forty-three years. Mr. Fandel, after serving as a laboratory assistant, came to work in the Personnel Office in 1952 and held various positions, the most recent being Manager of Labor Relations. His knowledge, commitment, caring and dedication are known to all who have had the pleasure of working with him. He will be sorely missed but has been working closely with Robert J. Lewis who has been hired to take over the Labor Relations management.

Other staffing changes include the addition of Judith F. DeCoursey and Susan Stone in the benefits administration area, the transfer of Ken Wolff from the Housing and Food Services Department to the Personnel Officer position vacated by Carl A. Belforti who moved out of state, and lastly Susan P. Gaskell who accepted the position as Director of Personnel at an area college.

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 typically 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 quantify 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 involve collecting data from approximately sixty universities and businesses across the country. The participants in these surveys reported data for approximately 23,000 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 35 outside surveys.

We conducted nine, separate, annual salary reviews covering 8,300 members of the Institute's faculty and staff.

We reviewed a total of 131 individual requests for reclassification in the Institute's Staff Classification Program, including 70 requests to assess newly created positions, and 61 promotional requests and requests to reevaluate existing positions.

We made substantial progress during the year in further developing personal computer systems to support our various activities. For example, a majority of the outside organizations that participate in our two national salary surveys have agreed to submit data on floppy disks, and we have developed a number of spreadsheet and database applications that facilitate the input and analysis of these data. We have also developed similar personal computer support systems that automate the analysis and record-keeping functions associated with the Institute's classification systems, including a "macro-driven" spreadsheet that expedites the rapid drafting of departmental organization charts.

In closing, I would like to express my thanks to my three wage and salary associates for their unflagging hard work and support throughout the year. It would be difficult to think of undertaking the varied and demanding tasks of this office without the generous assistance and wise counsel of Susan A. Lester, or the enthusiastic and effective support of our two colleagues, Dineen M. Doucette and Judy K. Raymond.

KERRY WILSON

BENEFITS OFFICE

This past year has been one of rebuilding for the Benefits Office. Forty percent of the staff has just completed their first year with us and we finally became fully staffed in April. Training has been an ongoing process for us as we brought these new individuals through an annual cycle of benefits administration. We have been encouraged by the progress and efforts of each team.

The office responded to 36,000 telephone calls during the year. We continue to decrease the number of lost calls. We are pleased to report that in the last two years the lost calls have decreased from 30-35% down to 15 to 18% and now down to an average for last year of 10%. Not only have more people been able to reach the Office, but we have noticed an increase in the length of calls and complexity of the information requests. BenTalk, our interactive phone system, handled an additional 9,000 inquiries.

For the first time the Benefits Office assumed responsibility for calculating pension estimates. An estimate package for plan members was developed and parts of the retirement package were redesigned to accommodate our involvement in this process. There was a major programming effort needed prior to and following implementation of the merging of the two pension plans into one plan. This impacted our ability to appropriately communicate the union negotiated retirement plan changes and provide maximum exclusion allowance calculations for TDA participants. Despite the delays, the Office managed to complete over 1,000 requests for pension estimates in fairly reasonable turnaround periods. We also counselled 156 employees who chose retirement this year.

The Benefits Office focused on continuing efforts to increase communications both through meetings and printed materials. We conducted a fall and spring series of information meetings designed to provide information on specific benefit plans. With the exception of the Tuition Assistance meetings, they were sparsely attended on Campus, and well attended at Lincoln Laboratory. The Office also participated in several informal benefits information discussions with various department support staff members. One hundred and eight orientation meetings were held throughout the year for newly hired employees. Plan booklets were updated and articles were published in TechTalk.

We completed a review of the funding and administration of the Long Term Disability plans. A recommendation to change both is currently under consideration.

The processing of Tuition Assistance and the Children's Scholarship applications and payments was significantly improved over the last twelve months. Our new Children's Scholarship Plan system contributed to this improvement.

The Office has made remarkable progress over the last year. In our continuing efforts to document administrative policies and procedures we are identifying opportunities to change and improve the way we do business. We have subjected ourselves to many changes over the past twelve months and as a group have managed to adjust at every step along the way. We are encouraged by the continuing support from senior management.

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 insure 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 and in the production of the staff telephone directory.

A new procedure was added to the telephone directory process. Network Services of Information Systems made available to the MIT community an on-line telephone directory using data which was transferred electronically from the Personnel database to the on-line directory. This office continues to provide monthly updates to the on-line directory.

After twenty some years of faithful service, the electronic filing system containing the Institute employment records retired and a new filing system was installed. This was a major effort involving the conversion of approximately 15,000 employment records. I would like to take this opportunity to thank the Records Staff for their effort and dedication to the project.

All of the terminals used by the Records Staff to update the Personnel database have been replaced with personal computers. The Staff Assistants are also utilizing the word processing function of the personal computer to generate the daily appointment and salary change letters. Letters are on the new laserjet printer that was purchased this year.

There has been a new appointment to Administrative Staff in our office. Cynthia Olson was promoted from Administrative Assistant to Supervisor, Faculty and Staff Information Services. Ms Olson is responsible for supervising all aspects of maintenance, including the updating of faculty and staff records.

In the systems and programming area, there continues to be a substantial increase in the demand for modifications and reports. Approximately 500 programs are maintained in the office, representing salary reviews, survey, benefits statistics, labor relations statistics, reconciliation reports, departmental information listings and labels.

A considerable amount of time was spent developing and modifying programs and setting up a process that enabled Wage and Salary, Benefits, and Labor Relations to independently download files to their local workstations for further manipulation and analysis. Several "menu systems" were developed which allow users to select the programs from the menu. Also, "area applications" containing specific programs have been created. This allows users with the proper authorization to access the particular application and run the program, thereby eliminating the need to make

the request to our office. Presently the Wage and Salary Office application contains 70 programs and the Benefits Office application contains 50 programs.

A new Equal Employment application was developed in Fourth Dimension for the Equal Opportunity Office. Using a NATURAL program and MIDAS, the Equal Employment application is populated with data from the Personnel database.

Whenever possible, we are continuing to send electronic files to the Payroll Office of the Comptroller's Accounting Office for automatic updating. This year for the W2 forms the Payroll Office accepted an electronic file containing home address information. We have also been discussing ways of eliminating duplication of effort by both offices.

While we have made some progress in the systems and programming area, we have been hindered by the technology of the current system. An enormous amount of time was spent this year evaluating and selecting a human resource package that will meet the needs of the Personnel Office and the MIT community. A proposal recommending a new system was placed before the Administrative Computing Steering Committee of the Institute in January. We are still awaiting a final decision.

CLAIRE L. PAULDING

LABOR RELATIONS

In general the Labor Relations Office is responsible for negotiating and administering the collective bargaining agreements with 5 bargaining units representing approximately 1,700 MIT employees. Duties also include representing MIT in grievance arbitrations and before administrative agencies.

During 1989-1990 four new 2-year agreements were negotiated. The Director of Personnel served as the chief spokesperson for the contract negotiations with the two Service Employees' International Union bargaining units on Campus and at Lincoln Laboratory. The Manager of Labor Relations was the chief spokesperson for the Institute wide negotiations with the Research, Development and Technical Employees' Union and the MIT Campus Police Association. These agreements provided for reasoned wage and benefit increases within our budgetary constraints. A major accomplishment was the merger of the Retirement Plan for Employees (RPE) with the new MIT Retirement Plan which will now include Service Staff Employees as well as other MIT employees. The introduction of a new pension plan complicated negotiations and led to a rather prolonged and difficult round. However all agreements were successfully concluded without incident.

This section also began a major training program on current labor relations developments. The program began with a briefing of Administrative Officers and has continued with smaller, informal departmental meetings.

The number of grievances and arbitration hearings has remained constant at a relatively low level compared to some prior years.

We recently concluded negotiations for a new two-year agreement covering the period July 1, 1990 through June 30, 1992 with the International Union of Plant Protection Employees, Local 14. IUPPE represents security officers at Lincoln Laboratory. While the IUPPE membership ratified the new agreement prior to July 1, 1990, that vote was challenged by a former union official on grounds that the vote did not comply with the union's by-laws. A second vote is now scheduled for after July 1, 1990 and we anticipate that the agreement will be ratified a second time.

ROBERT J. LEWIS

PERSONNEL SERVICES AND EMPLOYMENT

Personnel Officers continue to provide a full range of employee relations consulting services to employees and supervisors encompassing assistance with staffing, job counseling, salary administration and conflict resolution. They have been able to offer limited training programs including such efforts as policies and procedures workshops for both union and non-union supervisors, coordination of AIDS awareness training for specific departments and a review of grievance procedures for a group of area managers. Personnel Officers continue to provide

answers to a high volume of requests regarding policy interpretation, assistance with individual job searches and guidance in performing various personnel functions.

Employment Activity

This year brought about a change in the employment picture which appeared to reflect the changes in the Massachusetts economy. There was a decrease in both the number of positions posted and the number of individuals hired by the Institute. The volume of both applicants and resumes increased.

During the 1989-1990 fiscal year 868 vacant positions were posted, a decrease of 19%. These included 501 support staff, 164 administrative staff, 17 academic staff, 137 research and 49 service staff. Personnel Office staff interviewed 1,448 applicants for support staff positions, a 34% increase over 1988-1989. In addition 13,764 resumes were processed primarily for administrative, research and academic staffs. With regard to hiring statistics, 624 individuals were hired as new employees, a decrease of 31%. 187 people transferred to other positions within the Institute and 15 former employees were rehired.

Last fall, the Personnel Office changed its weekly listing of open positions, *Positions Available* which appears as a supplement to *Tech Talk*. Beginning in January 1990, *Positions Available* is now published every other week and lists all available full-time positions as well as a separate section for all part-time positions. A new communications page, *The Back Page*, was added as the last page of the publication. This page provides information about members of the Personnel Office Staff, personnel policies and procedures, benefits and a question and answer column.

Our recruitment advertising agency continues to provide us with their expertise in designing and creating recruitment ads for Institute Departments in various newspapers and journals. One of their recruitment ads for Information Services won a coveted award for creativity from the *Personnel Journal*. The agency also worked with us to prepare an updated recruitment brochure to help attract qualified applicants to MIT.

SALLY H. HANSEN AND ELIZABETH K. MULCAHY

CHILD CARE OFFICE

The Child Care Office was staffed by one full time administrative assistant, Jill-Beth Sweeney, and two three-quarter time administrators. New job descriptions reflect new areas of involvement and responsibility for Kathy Simons, Child Care Office Administrator, and A. Rae Goodell, now titled Coordinator of Parent Programs. The Office staff successfully maintained services during the Administrator's three-month maternity leave. Kathy Simons continued to staff the MIT Faculty Committee on Family and Work and analyzed survey results and outlined options for MIT response in the area of dependent care.

The Child Care Office experienced an increase in the number and complexity of counseling contacts with MIT parents. The Office provided 530 referrals to MIT-affiliated families, representing a 32% increase over 1988-89, and a 77% increase over the last three years. The majority of counseling was provided individually; a monthly group counseling format was introduced for expectant parents and its use will be expanded somewhat next year. A new database program was developed to store information on parent contacts and child care needs and to produce selective mailing lists.

In response to community requests, the Office has significantly expanded the information it makes available to parents around the needs of and resources for school-age children and special needs children, around issues of dual-career families and workplace issues of special concern to working parents. Parent workshops were offered on the average three times per month

throughout the year. The spring Parenting Workshop flyer was distributed Institute-wide and helped update and expand the mail list. A new support group for graduate student and postdoctoral parents was co-facilitated by Rae Goodell and Dawn Metcalf, MIT Social Work Service.

Technical assistance to MIT child care programs and providers included arranging joint training for staff at Technology Children's Center (TCC), LINCC, and the family day care network, help with the establishment of a scholarship program at TCC, and continued work to resolve family day care licensing difficulties in the Westgate low-rise. At TCC, full enrollment was maintained all year with waiting lists of roughly 50 children per program, with considerably less staff turnover than last year.

At Lincoln Laboratory, Carol Stokes became the new Director of Child Care Services. Ms Stokes, who reports to the Assistant Director of the Laboratory, managed the opening of the Child Care Office, providing resource and referral services through Workplace Connections, Inc., as well as the opening of LINCC, a day care center for infants and toddlers in the "Energy House" on the Minuteman Vocational-Technical High School campus. Construction of a new center to serve 65 children from infancy through preschool was begun with plans to open in the fall of 1990.

KATHY SIMONS

Public Relations Services

A number of common themes characterized the activities and concerns of the various offices in the Public Relations Services this year -- all having to do with communications and community.

Within MIT, there is, we believe, the need to create a greater sense of belonging and shared mission among all members of the MIT community. There is a growing diversity within MIT-- demographically, to be sure, but also in terms of a greater diversity of academic interests, lifestyles, and points of view. Communications could work much more informally at a time when MIT was smaller and more homogeneous in population and purpose. There is, now, a need for greater access to policies and information generally, for a sense of belonging, of being heard. There are many paths to take here. We are exploring the creation of a computer-based, networked information system -- to take advantage of the growing computer literacy here. We are assessing the signage at the Institute, so people can find their way around more easily. We will continue to report on issues of widespread campus concern in the pages of Tech Talk, in such a way that the paper reflects more fully the varying points of view in this community. And we will continue to help organize campus-wide events -- whether in the form of celebrations, lectures, memorial services, or colloquia -- that serve to nurture the sense of community at MIT. When considering ways to mark important events in the life of MIT, to discuss issues of common concern, to honor members of this community for their achievements, we must continue to do so in ways that draw in all who make up this special place -- faculty, students, staff, and alumni.

There is a particular constituency within MIT that, we believe, needs more complete and coordinated support services, and that is the international community. We have 1,300 international faculty and staff, 2,000 international students, 2,400 visitors from other countries each year. This year, the Provost appointed a faculty committee to review MIT's international institutional relationships and policies. In light of the fact that MIT's population is decidedly international in character, we believe that consideration should be given to reviewing and reorganizing the support services for international faculty, students, staff, and long-term visitors as well.

MIT's constituencies extend beyond faculty, students, staff, and alumni, of course. One of our primary missions is to increase MIT's visibility in the world. We will continue to bring MIT people and issues to the attention of the national and international media -- in order to enhance public understanding of science and technology, to attract the best possible students, to generate support for the *Campaign for the future*, and to generate goodwill toward MIT among the general public as well as our own community.

One of the ways in which we keep in touch is through published communications -- and one of the themes in our department this year has been the new age in communications, also known as desk-top publishing. We have been able to achieve cost savings within our own operations, and have seen the computer emerge as a design tool that facilitates the creative process. The same is true for departments throughout the Institute, and we have seen more people become their own publishers, so to speak. In addition to using computer-based typesetting and design within our own area, therefore, we intend to provide more design and production assistance to those offices around the Institute that are using computers to aid in their published communications.

It has been a good year, filled with changes and growth. I would like to salute here all of my colleagues in Public Relations Services, whose spirit, imagination, and sense of service make such a difference to MIT.

KATHRYN W. LOMBARDI

COMMUNICATIONS OFFICE

The Office serves as publisher as well as editorial and production consultant for major annual Institute publications: the Reports to the President, the Report of the Treasurer, the Summer Session catalogue, Courses and Degree Programs (the main catalogue), and the telephone directories. Much of the Office's activities this year had to do with taking fuller advantage of the desk-top publishing capabilities in this and other offices throughout the Institute, in an effort to produce more timely, cost-effective publications.

The collaboration between this Office and the Registrar's Office in producing the Courses and Degree Programs has been a major step in making use of electronic publishing and data-base systems, and we expect to fine-tune the communications links between the two offices this coming year. The Communications Office revised its charging policy for this catalogue, so that all applicants are now charged a fee for the catalogue. This measure was implemented to offset rising printing and mailing costs. The Office is now responsible for all aspects of distributing Courses and Degrees, and has taken measures to improve the timeliness and tracking of delivery.

The Registrar's Office has requested that the Communications Office assume more responsibility for the publishing of the Summer Session Catalogue. Therefore, in addition to typesetting, printing, and distributing the Catalogue, the Communications Office will collect all information appearing in the book from each department that supplies copy.

This past year, the Office supplied camera-ready grid sheets to all offices preparing a Report to the President, with the result that the book was published earlier than in years past, and with a more uniform appearance. Both versions of the Report of the Treasurer were produced using in-house publishing software in cooperation with the Comptroller's Accounting Office.

The Student and Staff Telephone *Directories* are being restructured and redesigned to be parallel in structure. In addition, the "grey pages", or index, is being reconfigured with the help of Information Services.

Other publishing projects during this year included: an updating and reprinting of the "Walk Around MIT" guide; and Tech Talk supplements for Dr. Gray's annual report, the roster of the Institute committees, and the Report of the Accreditation Team. Efforts are being made to have the committees roster put on-line in the Office's publishing software, so that we will have an on-going current listing and will be able to save time and dollars in publishing the listing each year.

Personnel

Changes in personnel had a great impact on the Communications Office. In August, Editor and Production Manager Nancy A. Ferrari left and was replaced that same month by Ruth T. Davis. In December, Marianne Charny assumed the restructured position of Senior Office Assistant. A third change in staff occurred in March when the Communications Manager, Mark Wilson, left MIT after ten years to move with his young family to upstate New York. We will miss Mark's initiative, professionalism, high spirits, and caring for his colleagues.

RUTH T. DAVIS

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, and the Summer Session Office. Included among special events this year were the Institute Ball, the Harold Edgerton Commemorative Service, the "Downtown, Inc." Symposium, and the Media Lab's fifth anniversary celebration. Overall, Design Services undertook 332 graphic design and publishing projects in 1989-90.

In the computer area, many small projects were designed and produced on our electronic publishing system and coordinated through this office for the first time. Continued development of desktop publishing included the purchase of a Mac IIcx, a halftone scanner, several Adobe type fonts and a drawing program which helped significantly in the design and production of in-house publications. The Corporation Members booklet, the Sloan Fellows picture book, the Graduate Fellowships in Chemical Engineering brochure and the Killian Award program were among the jobs done on the computer. With the addition of new software programs, we have been able to streamline office procedures and make design publications more cost-effective. Typesetting costs dropped dramatically from FY89 to FY90 by \$44,200, providing healthy savings which we could then pass on to our clients.

With the proliferation of desktop publishing, efforts began this spring to develop and implement design guidelines and templates for Institute clients wishing to produce publications on their own, but lacking design skills. Templates would specify acceptable type styles, photos and trim size and would be used as guidebooks for desktop users. Work will continue in this area in the coming year, as our office addresses the issue of how to maintain institutional design integrity throughout the MIT community.

Personnel

The staff of Design Services during 1989-90 included Elizabeth Chimento, senior designer, Elizabeth Ferry, production manager, and Lee McMahon, administrative assistant/production coordinator. Anne Hubbard, who joined our staff in the spring was hired as a senior designer/production manager.

CELIA 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 to visitors; assisting the international faculty and staff; and coordinating Institute conferences and special events.

Public Relations and Information

This section of the Center answers and directs to other offices telephone and office inquiries from the public and MIT community; distributes 40,000 pamphlets, brochures, guides, and catalogues; is a clearinghouse for mail addressed to MIT; maintains the official Institute mailing list and roster of faculty and presidentially appointed 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, John E. Schnyder (Class of 1990), was a dedicated and conscientious head guide with outstanding leadership qualities. He trained and scheduled 24 student guides to conduct tours for 8,102 visitors. Of these visitors, 2,881 were prospective students, 954 were international visitors, and 4,267 made up the remaining total. A selected group of visitors who took tours this past year filled in a visitor questionnaire that informed us that they were particularly interested in: academic opportunities; visiting classrooms, laboratories, Strobe Alley and "Doc" Edgerton; Athena; UROP; and talking with faculty and students. Entrance requirements, financial aid, and student life were concerns uppermost in their minds. The majority reported that after their visit, their perception of MIT had changed to a more human and friendlier place. Working closely with John during the summer as full-time guides were Kathryn L. Sand, Class of 1992, and Anne E. Tuttle, Class of 1990.

During the past year, an ad hoc group known as the Information Access Working Group (INFACS) met regularly to discuss and investigate the informational needs of the MIT community and visitors to the campus. This group included representation from the Information Center, Information Systems, Planning Office, Office of the Vice President in the Office of the President, and Office of the Senior Vice President. The initial task was to identify issues, help provide improved campus navigation aids, and develop consistent, updated information about activities and locations from a number of sites around the campus. Discworks Consulting Associates was hired to do a pilot study to map the flow of visitors and information at MIT. From their recommendations, the INFACS group submitted a proposal to recommend the following: 1) placement of consistent, attractive, highly visible campus maps at strategic locations around the campus; 2) development of indexed pocket-size maps for visitor use; 3) addition of temporary, portable bulletin boards to avoid poster pollution while other multi-media options for the distribution of information currently supplied by posters are being developed; 4) start-up funding for a special computer-based program that will provide information on a range of topics such as campus events, class schedules, job openings, and a wide variety of the services provided by MIT's many academic and administrative offices; and 5) review of the potential for cable television to mitigate existing overextended paper information for the student population and explore the opportunity for providing a range of services not offered by the present system.

Other activities of the Center included: arranging for MIT to be represented at the inaugural ceremonies of 23 other universities; making arrangements for 644 individual international visitors to be given special tours and to meet with faculty and academic staff.

Special Events

Special events this year included memorial services for two members of the MIT community -- Professor Richard B. Adler and Institute Professor Emeritus Harold E. "Doc" Edgerton; a community-wide ball attended by over 1200 faculty, students, staff, and alumni honoring President and Mrs. Gray; the Killian Award lectures; and -- as always -- Commencement.

A new feature of Commencement this year was the hooding ceremony for doctoral recipients, held on the Sunday preceding the Commencement Exercises. The ceremony was held in Kresge Auditorium, which was filled to capacity with family and friends who came to share in this very special event where over 250 doctoral candidates received their hoods. The featured speaker on Commencement Day was the Honorable Virgilio Barco (Class of 1943), President of the Republic of Colombia, who received a standing ovation from graduates and guests alike. The reception following the ceremony was an occasion for families, friends, and members of the MIT community to celebrate and even to dance to the music of Associate Provost Keyser and the Intermission Trio, Plus.

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 50 to 1,500. This past year, the Office coordinated 19 such events, which brought more than 5,000 visitors to the campus. Examples of these conferences and meetings give an indication of the range of interests and activities among our faculty and staff: the National Puppetry Festival, the V Bi-National Colloquium of the Humboldt Foundation, the meeting of the Society for Ethnomusicology, Energy and the Environment in the 21st Century, International Conference on Particles and Nuclei, and the Conference on Waste Management Practices.

This office also handled the arrangements of more than 100 recruitment presentations by companies and other organizations that visit MIT in conjunction with the Office of Career Services and Preprofessional Advising.

International Scholars Office

The International Scholars Office, formerly the International Visitors Office, moved from the Information Center to much needed larger quarters in Building 4. The Institute was most fortunate that Frances Helmstadter, formerly advisor to foreign academic staff at Cornell University, accepted the appointment as head of the International Scholars Office, succeeding Virginia (Ginger) D. Lyons.

The political situation in the People's Republic of China that became critical last June continued to be a concern among Institute faculty, staff, and scholars. The Provost supported and funded a temporary position to work with the International Students and Scholars Offices to advise and counsel the Chinese students and scholars applying for extensions and changes in their visa status. Dr. Bette Davis was hired for this academic year to work with this group, who were desperate for information and advice about their safety and the safety of their families in China as well as their ability to stay in the United States to study and work. Dr. Davis identified community groups concerned with PRC

matters, advised and counseled Chinese students and scholars on immigration and personal matters, kept abreast of legislative proposals and President Bush's efforts to relieve this situation, and advised Institute faculty and staff on changing regulations and opportunities for the Chinese. Dr. Davis earned the confidence of all who turned to her for information and advice, reducing the already extended pressure on the ISO.

It has been of special concern this year that the length of time is increasing before scholars, assistant professors, and other researchers can apply to change status to permanent residency. This causes a serious inconvenience to our international faculty and may threaten the Institute's ability to attract highly qualified teachers and researchers. Third-preference immigrant numbers are backlogged for 16 months, and this unavailability of numbers will increase in the months ahead. This delay is of critical importance to faculty members whose work involves collaboration and attendance at international symposia. Several bills are pending in Congress that would substantially increase the annual allocation of third-preference immigrant numbers, but these bills have other undesirable features. We will continue to work with Ronald P. Suduiko, Assistant to the MIT President for Government and Community Relations, and Parker Coddington, Legislative Liaison at Harvard University, to carry the message to our legislators that we need relief from the serious obstacles to hiring the best faculty and research staff members.

The database for the Office continues to be a challenge. The staff is improving the record-keeping and data processing with the assistance of David R. Martin, Class of 1992, an excellent work-study student. The programming needs have been analyzed by Information Service, and we expect to network the computers to other offices so that more staff members will have direct access to our data. In addition, we would like the program to capture the immigration history of the scholars.

Personnel

A salute goes to the entire staff in the Center, who maintain their humor, professionalism, and sense of service under sometimes extraordinary and stressful conditions. Frances Helmstadter who began in August with a broad knowledge of immigration rules and regulations and maintains a sensitivity that is necessary for her position; her administrative assistant, Salvatore Mazzone whose charm and initiative are more than appreciated not only by the office staff but by the many international faculty and scholars; Lillian Whelpley whose service to the Institute is legendary; Gayle Fitzgerald who gave birth to a beautiful son, Thomas Joseph, but still managed to keep her workload up the highest standards and who worked full-time right up until the time of birth; Marie Seamon whose quiet manner conceals a strength that is applied to all her work; Patricia Ezekiel, new to the office but already an important member of the team; Terri Priest whose organizational talents are important to so many projects; Kathleen Barrett, on whom not only the Information Center but the Institute relies constantly; and once again to Donald Ferland on whom the Director depends so heavily and who appreciates his skill, competence, efficiency, and humor.

MARY L. MORRISSEY

NEWS OFFICE

The News Office is the principal source of public information about MIT for the local, national and international news media. On breaking stories, the News Office has to be prepared for nearly instantaneous, thoughtful response when the news media begin to call. The Office also deals with many calls from the general public on matters that range from requests for research papers to pleas for information from an MIT expert on an extraordinary number of topics.

The News Office also publishes the official campus newspaper, MIT Tech Talk, a tabloid with eight or twelve pages, which often carries inserts prepared by other MIT offices. One of the most significant changes this year was the January inauguration of a new, desktop-publishing design for Tech Talk, and the addition of MIT to its new name, MIT Tech Talk.

One of the year's major stories was a sad one, the death on January 4 of Professor Emeritus Harold E. "Doc" Edgerton, a towering MIT figure widely honored for his teaching, creativity, and good will. Recognizing his stature, ABC Nightly News saluted him as its "Man of the Week."

Another major national news story was the search for the fifteenth president of MIT, including the acceptance and subsequent withdrawal by Professor Phillip A. Sharp, and concluding with the election of Charles M. Vest, provost of the University of Michigan, at a special meeting of the Corporation on June 18, and an enthusiastic reception by the faculty and other members of the MIT community later that day.

Earlier that month, reporters from the United States and abroad covered MIT's 1990 Commencement Exercises, at which the speakers were President Gray and Virgilio Barco, president of the Republic of Colombia.

A significant generator of publicity again this year was *Made in America*. Thirteen months after its May 1989 release in a hard-back edition by MIT Press, it continued to command Page One mention in leading newspapers as a major and influential study of industrial productivity. The News Office played a significant role in helping secure \$2 million of funding for a proposed NOVA series on PBS television based on the book. Its authors made dozens of appearances across the nation and in Mexico and Japan, carrying the message that people must be open to change and be ready to take the long-range view of economic benefits.

Another MIT Press book, *Downtown Inc.*, by Professor Bernard Frieden and Associate Professor Lynn Sagalyn, was the subject of a symposium in Los Angeles, covered by the news media who were assisted in public relations by the News Office and a local consultant.

The Bank of Boston study, *MIT: Growing businesses for the future*, continued to get attention.

A new type of project for the News Office this year was the compilation of a report, *MIT Educational Outreach Programs*, an 18-page compact guide prepared on the basis of responses to a News Office questionnaire to MIT faculty and staff. Maintained on a

database within the Office, this activity provides an infrastructure for current and future public relations initiatives, and also supplied MIT academic and administrative offices with new information. Many of the people who were doing this outreach at MIT had no idea so much else was going on in the field here.

Other topics that brought significant attention to MIT were:

1. The question of global warming, with Professor Richard Lindzen casting doubt on the measurements and conclusions of the global warming advocates.
2. The report of the Quality Education for Minorities Commission, headed by Dean of Student Affairs Shirley M. McBay.
3. The appointment of Professor David Baltimore, director of the Whitehead Institute, as president of Rockefeller University in New York.
4. Provost John M. Deutch's letter to the Secretary of Defense, urging the abolition of the discrimination against homosexuals in the Reserve Officer Training Corps and the continuation of ROTC on college campuses.
5. The continuing controversy over the work of former MIT researcher Theresa Imanishi-Kari being investigated by Congressman John Dingell.
6. The photographs by MIT aeronautics and astronautics professors, taken during a visit to Moscow, of the previously unconfirmed Soviet lunar lander vehicle.
7. The continuing economic controversy regarding the U.S. and Japan, and the question of whether American universities should be free to pursue knowledge and funding from international sources.
8. The question of divestment of United States corporations with operations in South Africa, and the arrests of students on the MIT campus.

Personnel

In September 1989, Lynn Heinemann, senior secretary for the past six years, resigned to take a position in the Office of the Arts, where she assists China Altman, Director of Communication for the Arts and also a former member of the News Office. In November 1989, Lisa Damtoft joined us as senior staff assistant, succeeding Lynn. In April 1990, Mary Thompson Galindo left MIT to take care of her twin girls, and her place as receptionist was taken by Cynthia Consentino.

A salute to them, and all the other News Office staff -- Robert DiIorio, Charles Ball, Eugene Mallove, Naomi Chase, Donna Coveney, Joanne Miller, Elizabeth Thomson, and Myles Crowley -- who serve the Institute well.

KENNETH D. CAMPBELL

Quarter Century Club

The MIT Quarter Century Club membership now totals over 2150, with each member having served the Institute for more than 25 years. At the annual meeting, which was held in March, a total of 90 new members were inducted. The other Club functions are the picnic held in August, attended by approximately 1000, and the holiday gathering in December. The staff of the Club also organizes and administers the Institute's United Way drive. Campaign receipts for 1989 totaled \$261,047, against a target of \$290,000. The number of contributors was approximately 2400. An extensive project to computerize the campaign records was completed allowing for much greater reporting capabilities.

The Institute Retirement Dinner is organized and administered by the staff for the office of the President. June ceremonies were held in Walker Memorial for a record 161 retiring employees and their guests, as well as supervisors, administrative officers and department heads.

The office also administers the MIT Activities Committee (MITAC) which organizes recreational and cultural activities for the community. Mailings are done 10 times annually to announce the various programs; last year 67 events were sponsored in addition to ongoing ticket sales for movies and museums. There is also a satellite committee at Lincoln Laboratory that handles sales which are then reported through this office.

The Club provides service and space to a chapter of the American Association of Retired Persons, Inc. (AARP) which has approximately 250 active members. They have a 16 member board which meets quarterly. Additionally, they organize 8 campus chapter meetings annually and sponsor several travel programs for the membership.

An extensive travel program is organized by the manager and reviewed by a committee for the alumni, retirees, and the Institute community. Last year, working with eight different companies, a total of 31 trips to various destinations worldwide was offered with most of them including lecturers from various research centers or co-sponsoring universities.

The Club was founded in 1950 and became an Institute administrative department in 1978, reporting to the Vice President in the Office of the President. There are four officers and a 10 member board of directors with Daniel H. Gould serving as Chairman of the board. Full board meetings are held twice annually. Staff changes during the year included a promotion to Assistant Manager for Nanci A. Drago; the departure of Donna Meuse and the arrival of Barbara Noble.

ANN P. BRAZIER

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, 1990, the following members completed their designated terms of service: Joan T. Bok; Michael M. Koerner '49; Fuad U. Muhammad '87; Robert J. Richardson '54; and Robert A. Swanson '69.

Elections to Term Memberships

The following eight members were elected to the Corporation for five-year terms beginning July 1, 1990: Samuel W. Bodman '65; Denis A. Bovin '69; Jerome H. Grossman '61; John M. Hennessy; George M. Keller '48; James A. Levitan '45; Edward H. Linde '62; and Harris Weinstein '56. In addition, Bernard Loyd '85 was elected to a five-year term to begin October 1, 1990. (Dr. Bodman and Mr. Keller have each served a previous five-year term. Mr. Weinstein served during 1989-90 as an ex officio member of the Corporation in the position of Alumni Association President.)

Election to Life Memberships

Two individuals were elected to Life Membership, effective July 1, 1990: Colby H. Chandler '63 and Emily V. Wade '45. David S. Saxon '41 was also elected to Life Membership, effective immediately following the completion of his term as Chairman of the Corporation.

Ex Officio Members

At a special meeting on June 18, 1990, Charles M. Vest was elected MIT's fifteenth President, effective October 15, 1990. (See report on Special Meeting below.)

On June 30, 1990, Harris Weinstein '56 completed his term of service as President of the Alumni Association and was succeeded by Christian J. Matthew '43.

Transfer to Emeritus Status

At the October 6 meeting of the Corporation, the Chairman read a tribute to Irene du Pont, Jr., '43, who, in accordance with Section 5.1 of the Bylaws, had requested early transfer to emeritus status, effective July 1, 1989. Mr. du Pont was later presented with an MIT wristwatch engraved with his name and the years of his service as a Life Member.

At the June 4 meeting of the Corporation, the Chairman noted that on May 30, 1990, President Emeritus Jerome B. Wiesner 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. Saxon commended Dr. Wiesner on his long years of distinguished service to MIT and presented him with an MIT wristwatch engraved with the dates of his term as Life Member.

Deaths

At the December 1 meeting of the Corporation, the Secretary presented memorial resolutions honoring Life Member Emeritus H. W. McCurdy '22, who died on November 13, 1989.

At the March 2 meeting of the Corporation, the Secretary presented memorial resolutions honoring Term Member E. Rudge Allen '48, who died on January 5, 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 1989-90 the elected members were W. Gerald Austen, Edward E. David, Jr., Joseph G. Gavin, Jr., Shirley A. Jackson, Carl M. Mueller, Morris Tanenbaum, and Mary Frances Wagley.

In 1989-90 the Executive Committee held ten regular monthly meetings, and five special teleconference meetings in February and in June. The latter were devoted to reports and actions on the presidential search.

On June 4, 1990, Carl M. Mueller completed his service as the senior trustee member of the committee, having attended 84% of the meetings held in the twenty years of his membership. His distinguished record included participation in three presidential search committees, two of which he chaired. He served also as Chairman of the Executive Committee's Salary Subcommittee for eight years.

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 1989-90 fiscal year under the chairmanship of Breene M. Kerr. Serving with Mr. Kerr this year were E. Rudge Allen, Frank T. Cary, Michael M. Koerner, Norman B. Leventhal, DuWayne J. Peterson, Jr., and John S. Reed. Michael M. Koerner completed his term on June 30, 1990. E. Rudge Allen, a member of the Committee since July 1, 1989, died on January 5, 1990. Each of these gentlemen, though members of the Committee for only a brief time, was an important contributor to the stewardship of the Institute's assets. The Wellington Management Company of Boston has continued as investment manager and advisor for publicly traded securities, both domestic and international, a relationship initiated over thirteen years ago. During the year, the program of investment diversification with domestic and international alternatives to publicly traded securities was continued. These alternative investments 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. Saxon were Norman B. Leventhal, Angus N. MacDonald, Carl M. Mueller, Rita A. O'Brien, and Robert A. Swanson.

The Membership Committee met formally twice, in October and December, for substantive discussions of membership matters. In the remaining months of the year, the members stayed in touch by telephone and mail to exchange recommendations and review nominations. 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 this year by Sarah A. L. Tabler. The other members of the committee were Fuad U. Muhammad, Megan J. Smith, Charles H. Spaulding, and Robin M. Wagner. The committee conferred a number of times during the 1989-90 academic year. There was an open meeting with students in November, 1989, and four committee teleconferences were held in January and February, 1990. The five members of the committee chose a ballot of ten nominees from a group of 99 candidates from the graduating classes of 1988, 1989, and 1990. The ballot was then sent to members of those three classes to elect a recent graduate to nominate through the Membership Committee for election to a five-year term. As noted above, Bernard Loyd '85 was the winner of the election held by recent classes.

Auditing Committee

The Auditing Committee was chaired again this year by Joan T. Bok and included Louis W. Cabot, Harold J. Muckley, DuWayne J. Peterson, Jr., and Charles H. Spaulding as members. Also serving on the committee this year by invitation was Life Member Emeritus J. Kenneth Jamieson. There were two meetings, one on October 5, 1989, and one on March 1, 1990. At each meeting the Auditing Committee members were joined by representatives of the independent public accountants, Coopers & Lybrand, together with appropriate members of the administration of the Institute.

At the fall meeting, the Committee discussed the Financial Statement for the Year Ended June 30, 1989, while the spring meeting was devoted to a synopsis of the activities of MIT's internal Audit Division and reviewing Coopers & Lybrand's audit plan for the year ending June 30, 1990.

Advisory Committee on Shareholder Responsibility

The Advisory Committee on Shareholder Responsibility (ACSR) met twice during the spring term to review 57 shareholder proposals on the proxies of 32 public corporations in which MIT is invested. The ACSR also held an open forum in the spring to allow members of the MIT community to express their views on the issue of MIT investments as related to South Africa.

The Committee also reviewed, in two separate discussions, the guidelines it presently follows for reviewing MIT investments in U. S. companies with operations in South Africa. As a result of that review, the ACSR reaffirmed its present guidelines and their relationship to the Statement of Principles. The ACSR also recommended that the MIT treasurer should write to any company in which MIT is invested, and which had been a signatory to the Statement of Principles and then opted to withdraw from South Africa, to state that MIT would expect the company to continue, to the extent possible, its support of the Principles through any South African entities with which it has continuing relationships.

The Executive Committee approved that recommendation and asked, in addition, that the secretary of the ACSR assemble further information for the Executive Committee about the attitudes and opinions among the black majority in South Africa concerning the question of divestment. There will be further discussion of this issue in the fall.

Corporation member D. Reid Weedon, Jr., continued to serve as Chair of the ACSR and Walter L. Milne as its secretary.

Corporation Joint Advisory Committee on Institute-Wide Affairs

The Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC) held five meetings during 1989-90. Emily V. Wade again chaired the committee. Other Corporation members serving on the committee included Joseph G. Gavin, Jr., Jennifer L. Lund, Rita A. O'Brien, Sarah A. L. Tabler, and Harris Weinstein (ex officio).

In September, CJAC finalized its report to the Corporation Committee on the Presidency (CCOP) on the agenda and critical issues facing MIT in the 1990's. The report was presented by Mrs. Wade at the annual meeting of

the Corporation in October and distributed to members of the CCOP and the Faculty Advisory Committee on the Presidential Search (FAC). In December, Walter Milne and Professor Henry D. Jacoby updated CJAC on the progress of the presidential search. They noted that CJAC's report was well received by the CCOP and the FAC, and that all candidates had received a copy prior to meeting with the CCOP.

The remainder of the year was focused on widespread concern in the MIT community about housing. CJAC did not conduct an independent study but rather gathered existing information and heard what was planned or underway to meet the housing needs of undergraduates, graduates, postdoctoral associates, and new faculty. The committee met with many of the principal people involved in addressing housing issues including: William R. Dickson, Senior Vice President; Associate Provost Samuel Jay Keyser, Chair of the Quality of Life Committee; O. R. Simha, Director of the Planning Office; Susan DeFord-Offner, Assistant Treasurer; Peter Elias, Chair of the Committee on Family and Work; Stacy A. Segal, Chair of the Student Housing Working Group; Michael J. Warwick, President of the Graduate Student Council (GSC) and an ex officio member of CJAC; and Julia J. Vail, a member of the GSC.

CJAC issued its own report on housing, urging immediate attention to housing needs at all levels to preserve the quality of education at MIT, and this report was read aloud by Mrs. Wade at the June meeting of the Corporation.

CJAC members were once again 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 become candidates for membership on the Corporation.

At its final meeting of the year, CJAC compiled agenda for 1990-91.

Corporation Visiting Committees

Since their establishment in 1875, Corporation Visiting Committees have influenced the course of education and research at MIT. Following biennial visits on campus, which include meetings with faculty and students, the committees report to the Corporation and provide important advice and insights to the Corporation, the administration, and the relevant departments.

During the academic year 1989-90 twelve committees held meetings:

<u>Fall 1989</u>	<u>Visiting Committee</u>	<u>Chair</u>
September 25-26	Mechanical Engineering	F. Richard Meyer, III
October 12-13	Civil Engineering	Frank S. Wyle
November 1-2	Materials Science and Engineering	E. Rudge Allen
November 16-17	Nuclear Engineering	Robert A. Charpie
November 29-30	Physics	Frank Press
<u>Spring 1990</u>	<u>Visiting Committee</u>	<u>Chair</u>
February 8-9	Athletics, Physical Education, and Recreation	E. Milton Bevington
February 13-14	MIT Sloan School of Management	Colby H. Chandler
February 28-March 1	Mathematics	Howard W. Johnson
March 6-7	Earth, Atmospheric, and Planetary Sciences	Breene M. Kerr
March 21-22	Aeronautics and Astronautics	Joseph G. Gavin, Jr.
April 25-26	Whitaker College of Health Sciences and Technology	W. Gerald Austen
May 2-3	Linguistics and Philosophy	Edward E. David, Jr.

All pending oral and written reports were completed for committees which had met in the academic years 1987-88 and 1988-89. Oral and written reports were completed for committees which met in 1989-90 with the exception of

two oral reports (Linguistics and Philosophy, and Whitaker College of Health Sciences and Technology) and two written reports (MIT Sloan School of Management, and Whitaker College of Health Sciences and Technology).

In 1989-90, 353 persons occupied 399 slots (105 filled by Corporation members, 138 filled by alumni nominees, and 156 by presidential nominees) on the Institute's 24 Corporation Visiting Committees. Membership included 20 percent women; 8 percent underrepresented minorities; 56 percent affiliated with corporations; 33 percent with academia; 4 percent with foundations; 4 percent with government.

Membership of the 24 Visiting Committees was replenished for the academic year 1990-91: 51 members completed their Visiting Committee service on June 30, 1990; 144 members were asked to serve an additional term; and 67 new nominees were invited to serve.

Following the death of E. Rudge Allen, Edward O. Vetter agreed to serve as acting chair, and oversaw completion of the written report for the Visiting Committee for the Department of Materials Science and Engineering.

MEETINGS OF THE CORPORATION

Orientation Program

On October 5, 1989, 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, followed by 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 6, 1989, the agenda included the annual reports of the President and the Treasurer as well as reports on behalf of the Auditing and the Membership Committees. In addition, there were two Visiting Committee reports, for the Departments of Economics and Mechanical Engineering. The Chair of the Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC), reported on that committee's efforts to seek from the broader MIT community ideas on the agenda and issues for MIT in the 1990's as an aid to the work of the Corporation Committee on the Presidency (CCOP). There was also a progress report from the Chair of the CCOP on the work of that committee. As he does at every meeting, the Vice President and Treasurer reported on the status of the *Campaign for the future*.

At this meeting the Corporation adopted resolutions honoring Virgilio Barco '43, MIT Corporation Member 1970-1980, for his courageous leadership as President of Colombia during a time of formidable challenge.

There was no formal program at the luncheon following the business meeting in order to allow the maximum opportunity for conversations among new and continuing members of the Corporation.

December Meeting

In his report to the Corporation at the meeting of December 1, 1989, President Gray presented the recommendations of the ad hoc committee on freshman housing that had reported through its Chair, Professor Mary C. Potter, at the Faculty Meeting in November, 1989. Following President Gray's remarks, there were a number of questions and comments and a lively discussion among the members of the Corporation. At the conclusion of the discussion, Chairman Saxon assured the members that the administration would be consulting with them further as it continued to explore a variety of solutions for the many issues associated with student housing.

Another item of special interest at the December 1 meeting of the Corporation was the presentation by Dr. Ellen Harris, Professor of Music and Associate Provost for the Arts, who undertook this new position in the Provost's Office in the summer of 1989. Professor Harris focused her comments on the state of the arts at MIT today. After

a summary of the range of activities in the arts available at MIT and the establishment of such new campus organizations as the MIT Creative Arts Council and the ARTSNET public relations group, Professor Harris concluded her remarks by emphasizing that our continuing goal must be to hold the same standard of excellence for the arts that is held for everything else at MIT.

Following the meeting, members of the Faculty Advisory Committee to the Corporation Committee on the Presidency and members of the Academic Council were guests of the Corporation at a luncheon at the Faculty Club. Dr. Thomas H. Jordan, Robert R. Shrock Professor of Earth and Planetary Sciences and Head of the Department of Earth, Atmospheric, and Planetary Sciences, gave a presentation on the earthquake in San Francisco on October 17, 1989.

March Meeting

The meeting on March 2, 1990, occurred not long after Professor Phillip A. Sharp withdrew his candidacy for the MIT presidency. There was extensive discussion on the process and the progress of the presidential search. President Gray reported on behalf of the Executive Committee, Carl M. Mueller reported on behalf of the Corporation Committee on the Presidency (CCOP), and Professor Henry D. Jacoby, Chair of the Faculty and a guest of the Corporation at the meeting, reported on the work of the Faculty Advisory Committee (FAC) to the CCOP. It was the strong sense of the meeting that the search should proceed deliberately with no specified time deadline. The members of the Corporation expressed confidence in the Corporation Committee on the Presidency under the chairmanship of Mr. Mueller and the excellent support provided by the Faculty Advisory Committee. Appreciation was expressed as well for the willingness of the Chairman of the Corporation, the President, and the Provost to remain in their positions until the search came to a satisfactory conclusion.

The members voted to enable Chairman Saxon and President Gray to continue in their respective positions beyond June 30, 1990, if necessary, until a new president was elected and took office.

During the business session there were demonstrations outside the President's House protesting MIT's policy not to divest its holdings in U. S. companies that do business in South Africa. There were similar demonstrations later at the Sloan Building, where the Corporation luncheon was held. The President had said in his report that morning that the Executive Committee would have an opportunity to review again this spring and fall MIT's policy with regard to investments in South Africa.

At the March meeting, the Corporation heard a report from Sarah A. L. Tabler as Chair of the Screening Committee on the nomination process by which a recent graduate of MIT is elected to the Corporation. Her remarks included a progress report on this year's selection process.

Following a luncheon at the Faculty Club, where Corporation members were joined by members of the Faculty Advisory Committee to the Corporation Committee on the Presidency, members of the Corporation met members of the Faculty and Administrative Councils at a reception in the President's House. It was noted with some sadness that the reception would be the last of many pleasant occasions on which the Corporation and the Councils had shared the hospitality of President and Mrs. Gray at the President's House.

Commencement Meeting

The Corporation held a breakfast meeting prior to the Commencement exercises on Monday, June 4, 1990. Several former members, who had attended the June 3 dinner honoring David and Shirley Saxon (see Special Events) were guests of the Corporation at this meeting. As is customary at the Commencement meeting of the Corporation, new Term and Life Members were elected (see above) and Commencement degrees were voted. In spite of the abbreviated time schedule, there were two Visiting Committee reports and reports from the President, the Vice President for Resource Development, and the Chair of the Corporation Joint Advisory Committee on Institute-Wide Affairs.

At the graduation exercises following the business meeting, 33 Corporation members marched in the academic procession, the largest number in many years. In addition, in the Guest of Honor Division, Dr. Gray and Dr. Saxon marched together for the last time in a Commencement procession as President and Chairman of the Corporation. Honorary Chairman Howard W. Johnson also marched in the Guest of Honor Division, escorting

the Commencement Speaker, former Corporation member, Virgilio Barco. Harris Weinstein, as President of the Alumni Association, was the Chief Marshal, and retiring Corporation member Robert J. Richardson was Marshal of the Corporation.

Following Commencement, Dr. and Mrs. Saxon held the traditional Chairman's luncheon in the Sky Room at 100 Memorial Drive. There was a very large attendance at this year's luncheon, which, thanks to the warm and gracious hospitality of the Saxons, has always been one of the most enjoyable annual events on the Corporation calendar. At the luncheon Dr. Saxon presented Virgilio Barco with an MIT pocket watch engraved to commemorate President Barco's memorable speech at the 1990 MIT Commencement exercises.

Special Meeting

On June 18, 1990, Chairman Saxon presided at a special meeting of the Corporation that had been called in accordance with Section 6.3 of the Bylaws. In attendance were 46 active members, including 5 ex officio members, and one member emeritus. After a report from Carl M. Mueller, the Chairman of the Corporation Committee on the Presidency (CCOP), and some additional comments on behalf of the Faculty Advisory Committee (FAC) from Professor Henry D. Jacoby, Chairman Saxon opened the floor for the nomination. Mr. Mueller moved the recommendation of the Executive Committee that Charles M. Vest, Professor of Mechanical Engineering, Provost, and Vice-President of Academic Affairs at the University of Michigan, be elected the fifteenth President of MIT. Shortly thereafter, Charles M. Vest was named the fifteenth President of MIT with the unanimous vote of the members present and eligible to vote.

Dr. Vest, accompanied by his wife Rebecca and their two children, Kemper and John, joined the meeting and offered brief acceptance remarks, thanking the members of the Corporation for their confidence and their warm welcome.

SPECIAL EVENTS

Corporation Dinner Honoring David and Shirley Saxon

On Sunday evening, June 3, 1990, more than 160 present and former members of the Corporation, together with spouses and guests and members and special friends of the Saxon family, gathered in the Grand Ballroom of the Ritz-Carlton Hotel in Boston to salute David and Shirley Saxon on the occasion of Dr. Saxon's retirement from the post of Chairman of the Corporation. At that dinner President Gray announced that the tennis courts to the east of Walker Memorial will be named in honor of the Saxons, and he presented the couple with a framed photograph of the courts. In his response, Dr. Saxon delighted the guests by remarking that he would especially cherish this picture of the courts showing Walker Memorial in the background, because he and Mrs. Saxon had met at a dance at Walker Memorial more than fifty years ago. Mrs. Gray presented Mrs. Saxon with a crystal pendant on which the familiar domed profile of MIT had been etched, and Howard Johnson, the Honorary Chairman, presented Dr. Saxon with a bound volume of letters of appreciation from present and past members of the Corporation. Members of the Saxon family who attended the dinner were recognized.

Naming of the Saxon Tennis Courts

On June 11, 1990, President and Mrs. Gray were hosts at an informal gathering at the President's House to celebrate the naming of the Saxon Tennis Courts. Unfortunately, the tennis tournament which was to have marked the occasion was rained out and will be rescheduled in the fall. In spite of the bad weather, MIT colleagues, friends, and tennis partners of the Saxons obviously enjoyed themselves greatly, as did the honorees. Royce N. Flippin, Head of the Department of Athletics, presented Dr. and Mrs. Saxon with specially made gold athletics cards that will admit them to the MIT athletics facilities and will not have to be renewed annually.

The annual meeting of the Corporation, on October 5, 1990, will be the last meeting under the gavel of David S. Saxon. On October 15, when Dr. Vest assumes the presidency, Dr. Gray will succeed Dr. Saxon as Chairman.

David Saxon's seven years at the helm leave to the Corporation and to MIT a mark of leadership and high quality that will endure. The trustees, the alumni body, and the entire MIT community have drawn extensively on David's wisdom and depth of experience, his fresh perspective and ideas, and his steady guidance on all matters that relate to the governance and the development of MIT's intellectual, human, and financial resources. By their frequent presence at MIT events and their warm hospitality, David and Shirley Saxon together have added a graceful human touch to this campus. We wish them well in the next chapter of their lives and look forward to continued association with them.

CONSTANTINE B. SIMONIDES

VICE PRESIDENT FOR FINANCIAL OPERATIONS

The Institute used \$7.5 million of unrestricted gifts, grants, and bequests and \$3.5 million of other funds to balance the Fiscal 1990 operating budget. The \$3.5 million of other funds included reserves and accumulated income from current funds. No funds functioning as endowment were used to fund the deficit.

It is important to note that the small deficit position in operations in Fiscal 1990 masks the underlying financial strength of the Institute. Academic funds continue to grow from endowment income which is not spent, and gifts, which are increasing significantly as a result of the success of the *Campaign for the future*, flow into current funds or endowment funds.

The Institute also designates a significant portion of unrestricted gifts as funds functioning as endowment rather than spend them to balance the operating budget. As an example, the level of unrestricted gifts, grants and bequests received as expendable or endowment funds during the Campaign through Fiscal 1990 is approximately \$64 million. About \$29 million of these unrestricted gifts have been expended either to provide the balance between expenses and revenues in the operating budget over these years or to provide for the purchase of academic property contiguous to the campus. About \$35 million has been designated as unrestricted endowment or funds functioning as endowment to strengthen MIT's financial posture for future generations of MIT faculty and students.

Other measures of financial strength are also favorable. Over the past five years the market value of all the endowment funds increased by 82% to a new high of more than \$1.4 billion. The investment income distributed for spending from endowment funds increased by 68% to \$61.5 million. Total borrowings increased by only 3% and the Institute's public debt continues to be rated at AAA.

To eliminate deficits in future years and bring operations into balance by Fiscal 1992, a new budget for Fiscal 1989 onward was developed. It includes reductions in planned levels of salary and employee benefits, decreases in administrative costs, increases in student related revenues, and greater benefits from the Campaign, primarily because of the increased income for endowed faculty chairs.

In Fiscal 1990, scholarships and fellowships totalled \$45.6 million, an increase of 14.5% over the Fiscal 1989 total of \$39.8 million. Of this total, \$23.4 million was used for undergraduate student financial aid and \$22.2 million for graduate students. Almost one-half of the total comes from outside sources for designated purposes. The remainder must come from investment income, gifts, and unrestricted or other Institute funds. The amount of unrestricted funds that were used to offset the shortfall from other funding sources for student aid in Fiscal 1990 was \$12.3 million, an increase of 12.0% over the Fiscal 1989 level of \$11.0 million. Of this total, \$9.5 million was used for undergraduate student financial aid and \$2.8 million for graduate student financial aid. The need to use MIT unrestricted funds continues because MIT maintains its policy of meeting the full financial need of all undergraduate students from the United States while federal and other sources of scholarships have not kept pace with the expenses of a university education. The small deficit in operations is one of the effects on MIT of assuring financial aid to these undergraduates regardless of financial need. We hope that our resources combined with outside scholarship support will permit us to continue this policy in the future.

The future will require continued careful management of our financial resources and a continued high level of gift support. We are very grateful for the generous giving of our alumni and friends.

Many members of Financial Operations have been involved in the budget control efforts the past year, along with their normal responsibilities. Additionally, 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.

We continued the past year with the Career Development Programs designed and implemented within the Financial Operations areas. These programs included the Financial Management Program (FMP), the Financial Workshops (FWS), the Individual Development Planning sessions (IDP), and the Summer Intern Program. I am grateful for the staff members who have both participated in the program and those that have been instrumental in the design, implementation, and presentation of these programs. They could not have been initiated and continued without the full support and effort of many Financial Operations members.

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, 1990, the total number of women administrative staff is 90 (42%), while underrepresented minorities are 21 (10%) of the administrative staff of 213. (In 1989, these figures were 89 (42%) and 19 (9%) of 213, respectively.)

Including support and service staff members, the percentage of underrepresented minorities is 51 (13%) of a total staff of 403. (In 1989, the figure was 52 (13%) of 411.)

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 40 (37%) out of a total administrative staff of 109. (In 1989, the figure was 43 (39%) out of a total of 111.)

The number of underrepresented minorities is 18 (9%) out of a total staff of 205. (In 1989, the figure was 21 (10%) out of 213.)

Office of Financial Planning and Management

The number of women administrative staff members is 6 (50%) out of a total administrative staff of 12. (In 1989, the figure was 5 (42%) out of 12.)

The number of underrepresented minorities is 5 (38%) out of a total staff of 13. (In 1989, the figure was 4 (31%) 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. (In 1989, the figure was 5 (21%) out of 24.)

The number of underrepresented minorities is 12 (16%) out of a total staff of 77. (In 1989, the figure was 12 (15%) out of 78.)

Office of Registration and Student Financial Services

The number of women administrative staff members is 27 (66%) out of a total administrative staff of 41. (In 1989, the figure was 26 (65%) out of 40.)

The number of underrepresented minorities is 13 (18%) out of a total staff of 71. (In 1989, the figure was 13 (19%) out of 69.)

Office of Sponsored Programs

The number of women administrative staff members is 8 (42%) out of a total administrative staff of 19. (In 1989, the figure was 9 (45%) out of 20.)

The number of underrepresented minorities is 3 (10%) out of a total staff of 31. (In 1989, the figure was 2 (6%) out of 32.)

JAMES J. CULLITON

Office of the Comptroller

THE COMPTROLLER'S ACCOUNTING OFFICE - CAMBRIDGE

Payroll

The fiscal year began with the allocation of considerable resources to the Institute's Contingency Planning Project (disaster recovery). The Payroll System was selected as the first system at MIT to establish a formal plan under which recovery procedures would be executed in the case of varying degrees of disaster. The programming and hardware aspects of the project have been successfully completed and only the editing of the final procedures document remains. Programming was completed to modify and redirect the Flexible Reimbursement Account Plan (FRAP) deductions to the Lincoln Fiscal Office which assumed the responsibility for issuing such payments. Our annual effort to comply with last minute federal tax reporting requirements was successfully completed in time to meet reporting deadlines. The project to merge the Lincoln Fiscal Office payroll function into the Campus Payroll System was begun in early calendar year 1990. The first half of that project was implemented in May when the monthly-paid employee categories were transferred to campus. The remainder of that project, which involves the transfer of the weekly-paid employees, is continuing and is scheduled for completion early next fiscal year.

Investment Accounting

During the past year a modified version of the Investment Accounting System was completed and made available for use to both the Investment Accounting Office and the Treasurer's Office. The new system now allows the user on-line capability to review existing reports, download reports into worksheet mode, and query ability to access information as desired. The system has also been revised to report on federal asset holdings that were previously not acceptable to the old system.

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 10,000 newly acquired items of moveable equipment were identified and tagged. The biennial inventory of items of moveable equipment continued with the buildings in the main and northwest campuses being completed. Two hundred thirteen final inventories were completed and submitted to the sponsor as part of closing out the contracts, grants, and agreements, etc. There were 531 financial reports prepared and submitted to various government agencies. Monthly reconciliation of the Accounting Office records with the Property Office records continued with very positive results. Corrections to both systems are being done on a timely basis and the credibility of the property records is very high. Forty-one thousand dollars (original acquisition cost) of excess government equipment was acquired. Four hundred ninety-two items of equipment with an acquisition value of \$260,000 were transferred between MIT departments as part of a reutilization program. Equipment, unneeded or unusable by the MIT Community, was sold for \$376,000 providing funds for replacement equipment. Most of the equipment available for reutilization or sale continued to be displayed at the MIT Equipment Exchange.

Release 1 of the new Property Inventory and Accounting System has been tested and is now being used in production. The preliminary analysis and system architecture for Release 2 of the new system has been completed.

The Society for Property Administrators, which is administered by the Property Office, conducted a three-day Property Management Conference at Marco Island, Florida, in November 1989. More than 150 attendees from the United States and Canada were present at the conference.

LINCOLN FISCAL OFFICE

The Lincoln Fiscal Office has been working closely with the Comptroller's Accounting Office to combine the payroll data bases in order to have a centralized Payroll Processing System. Electronic communications have been established between Lincoln and Cambridge and the Staff Payroll was successfully converted in May 1990. The other payrolls will be converted early next fiscal year. Significant benefits are expected from this process, including interactions with the Benefit and Personnel Systems.

Expansion and modernization of the Lincoln Fiscal Cashier's Office will be completed early next fiscal year providing a more efficient environment in servicing the Laboratory.

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 equivalents) 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, in some cases, requests for other audit services. Operational Reviews are underway and data processing capabilities continue to be strengthened.

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, in March 1990, of Office of Management and Budget Circular A-133, "Audits of Institutions of Higher Education and other Non-Profits," 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. MIT and Pennsylvania State University are currently participating as pilot sites for the initiative. Under the Fiscal Year 1990 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 1990 was consistent with the long-term strategy implemented in 1989 to allocate audit resources based upon an analysis of the risk involved. The primary focus is currently on Operational Business Systems reviews, with Data Processing Reviews and Departmental Reviews continuing to receive substantial coverage. Involvement at Lincoln Laboratory will be maintained. Assignments within the Lincoln Fiscal Office are included in the agenda for the year as are areas identified through a long-range plan developed in conjunction with laboratory management.

Personnel Changes

The following staff changes occurred within the Comptroller's Office during the past year:

New Appointments

Michelle M. Aimone
Technical Writer I

Thomas B. Cosgrove
Property Subcontract Administrator

Robert M. Damian
Assistant Auditor

Richard J. Heavern
Technical Supervisor

John D. Larkin
Property Auditor

Marie L. Ludwig
Technical Writer II

Carol E. VanAken
Financial Analyst

Stephen H. Zimmerman
Auditor II

Promotions

David E. Burnett
Accounting Officer

Patricia J. Finocchio
Manager of Systems

Deborah A. Gibson
Assistant Accounting Officer

Martin J. Kelly
Senior Staff Accountant

Elizabeth A. Lynds
Analyst/Programmer II

Philip L. Philips
Senior Accounting Officer

Marjorie E. Sciulli
Senior Staff Accountant

Promotional Appointments

Douglas J. LeVie
Staff Accountant

Michael F. McCarthy
Property Auditor

Denis W. Shield
Applications Programmer

Imelda Zepf
Staff Accountant

Retirements

Bernice A. Hogan
Property Auditor
8 years' service

Paul L. Smith
Property Accountant
35 years' service

Frank R. Wynne
Property Administrator
21 years' service

Resignations

Deena M. Anundson
Staff Accountant

Joanne C. Barrett
Assistant Accounting Officer

James F. Bixby
Senior Systems Programmer

Jo-Anne M. Chute
Property Auditor

R. Thomas Eirich, Jr.
Computing Trainer

Steven T. Holzinger
Consultant I

564 Vice President for Financial Operations

Frank J. Silva, Jr.
Assistant Accounting Officer

Paul L. Smith
Property Accountant

Edith A. Thompson
Accounting Officer

Wayne T. Turner
Accounting Officer

Cynthia C. Westhoff
Senior Analyst/Programmer

June R. Milligan
Property Auditor

Jolanda Scott
Staff Accountant

Chester T. Seymour
Auditor II-EDP Specialist

William H. Simpson
Technical Supervisor

Lynda B. Wellen
Auditor I

PHILIP J. KEOHAN

Office of Financial Planning and Management

FISCAL 1990 RESULTS OF OPERATIONS

Total operating expenses for the year were \$1,063.6 million - up 12.3 percent from the previous year. However, if you remove from expenses the distorting impact of changes in subcontracts, energy, and employee benefit costs, then you find that the programs of the Institute grew at a rate approaching the 6.5 to 7.0 percent level. In comparison inflation, as measured by the consumer price index for all urban workers, grew by 4.7 percent.

The Institute recorded a deficit of \$3.5 million which was some \$0.5 million less than the budgeted deficit of \$4.0 million. It should be noted that the deficit was funded through the use of \$0.4 million of income from current funds of the Provost, and \$3.1 million of income from reserves, such as the Research reserve and the Unexpended Commitments reserve. Thus, no "decapitalization" of the endowment occurred as a result of this deficit; i.e., no funds functioning as endowment were used to meet the deficit.

Despite the uncertainty in the operating budget, it is important to note that the recent deficit position in operations masks the underlying financial strength of the Institute. The success of the Campaign for the Future has resulted in the continued growth in restricted academic funds and in the resources available to support ongoing and new academic initiatives.

FINANCIAL PLANNING

The Coopers and Lybrand Management Consulting Group was engaged to study the mathematical model and planning process used by the Institute in deriving its financial projections. They concluded that the model is accurate and contains the main variables affecting MIT's financial position. They also concluded that the variance between projections and actual results could be lessened by better communication of program and policy changes to the office.

In a March 1989, article entitled, Background Paper on Educational Costs, Tuition, and Student Aid at M.I.T., President Paul E. Gray stated:

"Our objective in financial planning and budgeting is to achieve balance without using nonrecurring capital resources to meet recurring expenses."

This has long been a goal of the Institute. Despite the growing financial strength of MIT, achieving balance in the operating budget has been elusive over the last two decades as the Institute copes with the demands of the moment, be it energy inflation, competitive salaries, rising employee benefit costs, restraints on tuition increase, the need for financial aid from MIT sources, or simply new and worthwhile programs.

The crucial variables in the Institute's financial plan are the assumptions of salary and tuition increases. These two variables have the most impact on the projections of the financial results of future operations. Thus, any effective strategy for long term budget equilibrium must focus on the trade-off between compensation and tuition.

Faculty compensation is one of the largest elements of the net operating budget, where net operating budget is defined as that portion of the budget not supported by contracts, gifts, or investment income. While faculty salaries have a major effect on the bottom line, they also have the most potential for being funded from other sources, such as endowment.

A major effort to attain equilibrium in the operating budget is to move faculty salaries to Professorships (endowment). Named chairs can be raised through development efforts, the Institute's lifetime commitment to our faculty would be funded, and pressure on tuition increases would be relieved. Efforts of the Campaign have been directed toward the provision of endowment for faculty chairs and have been very successful.

These issues have been the focus of financial planning in fiscal 1990.

CAPITAL BUDGET

The Institute's capital budget increased from \$305.2 million at the beginning of the year to \$312.6 million at the end of the year. The project budgets include \$191.5 million for ten active projects and \$121.1 million for eight 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 \$108 million for the active projects and \$92 million for the future projects.

Major projects substantially completed during the year include the conversion and renovation of an existing early 20th century masonry manufacturing complex to a 190 bed graduate student residence. This air conditioned facility at 143 Albany Street contains 88 studio to four bedroom duplexes and is scheduled for occupancy in July 1990. Also substantially completed was the South Hall Ring at the Bates Linear Accelerator.

Total mortgage indebtedness for educational plant at June 30, 1990 was \$80,220,000 financed through the Massachusetts Health and Educational Facilities Authority.

FINANCIAL SYSTEMS

This was the first year that the new Budget Entry, Edit, and Review system (BEERS) contained data completely developed through the use of the system. This allowed the office to provide analytical support that was well beyond the capability of the office last year. The power of the system to track budget changes, to analyze data, and to make special reports became even more apparent as the year progressed.

MITBUD is a budgeting tool for developing department budgets and allows for the electronic input of those budgets to the BEERS system. As a part of the fiscal 1991 budget cycle a simplified, user friendly, version of MITBUD was introduced to the community. As a result, the electronic submission of budget data was up significantly.

The need to find the time to enhance and add new modules is also apparent, as is the need to resist adjusting the system to each short-lived exception that others might want.

PERSONNEL AND ORGANIZATION

During the year five staff members left the office for other pursuits. Richard M. Hill transferred to the School of Science as Assistant Dean for Financial Administration and Frances L. Davis transferred to the Telecommunications Office as Fiscal Officer. Both of these talented people will be missed in the office though they will continue to contribute to MIT in a major capacity.

Sarah Brady, and Robert Gulian left MIT for positions of greater responsibility or to pursue special interests. In addition, Gregory Thompson left to pursue other career goals.

As a result of the Coopers and Lybrand study, the addition of two staff members to the complement of the office has been approved. As of the end of the year the five vacancies had been filled and one of the two new staff members hired. As space limitations continues to be a problem, the search for the second new staff member has been postponed until the early part of the next fiscal year.

During the year Timothy W. Keohan joined the staff as Assistant Director of Automated Systems and will lead our systems effort. Lucia Ma joined him as an Analyst Programmer. Both of these people had previously worked in Administrative Systems Development. Junco Norton, who formerly worked in the Industrial Liaison Office, joined us as a Budget Officer. Robert Slauzis, who will join the office at the beginning of the new year as a Budget Officer is transferring from the Comptrollers Office. These four people bring some 28 years of MIT experience to the office.

Leslie A. Mulford became a Budget Officer during the year and will concentrate on the Capital budget. She has extensive experience in public financing of educational facilities as well as experience at another academic institution. Joining us as a Budget Officer at the beginning of the next fiscal year will be John Cunningham who comes to MIT after four years experience in the Office of Management and Budget of the Federal Government.

In closing, it is interesting to note that the current staff averages 1.6 academic degrees per person.

JOHN A. CURRIE

Office of Purchasing and Stores

Major projects accomplished or initiated this year include:

- (1) An ongoing program of user training and implementation of the new Electronic Requisitioning, Electronic Speed Order, and User Inquiry system (EREQ) commenced, on schedule, in May. This followed the development of a fully functional prototype system during the second half of the previous year, live testing at four departments and one laboratory during the summer, and, in the fall, the Administrative Computing Steering Committee's approval and funding of the first phase of the development of a production EREQ system.

Development included the migration of the EREQ system from the VAX 8550 computer, on which the automated Purchasing and Accounts Payable systems run, to a stand-alone MicroVAX 3600 computer, which was purchased the previous year, to provide "task-to-task" communication with the VAX 8550 computer. Use of a stand-alone machine for this application was necessitated by performance, security, and system access considerations due to the required open system design needed to provide Institute-wide access, to maintain existing Purchasing and Accounts Payable application systems' security, and to preserve VAX 8550 resources.

Development also included the successful establishment of Institute-wide access capabilities to the MicroVAX 3600 via the campus network, the 5ESS digital switch, or analog telephone lines.

During development, comprehensive software and hardware configuration and user manuals were prepared and a training room was established within Department spaces. The training room was equipped (with equipment which duplicated that which is commonly used on-campus) to accommodate the training of twenty users each day (two classes each day). From early May through the end of June, over 400 Institute members were trained to use the EREQ system. As stated, this is an ongoing program of training and implementation. A base of 3,000 eventual users of the EREQ system is projected.

The first phase of the development of the production EREQ system provided or will provide for the following capabilities:

- Electronic Requisitioning. Users are able to create, store, display, and forward requisitions to the General Purchasing Office for review and purchase order issuance.

By the fall of the coming year, users will be able to forward requisitions electronically to other on-campus purchasing locations, to the Office of Laboratory Supplies, and to other departments which are Institute sources for goods and services (e.g. Graphic Arts, Audio-Visual, Food Services, etc.).

- Electronic Speed Orders. If the value of a requisition is \$500 or less, the user is able to specify the immediate assignment of a purchase order number which he/she can promptly relay to the vendor.
- Access to Purchasing 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 Accounts Payable systems.

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.

During the summer of the coming year, approval and funding will be sought to proceed with the second phase of the development of the production EREQ system. This phase will provide full routing capabilities to 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; and (ii) to other administrative offices for reviews and approvals, as required by MIT policies and procedures and Federal contract and grant provisions.

- (2) In connection with the development of the EREQ system and the need to increase security and to limit user access and privileges to the account numbers and dollar levels which account supervisors have authorized, a new automated Signature Authorization system was developed and implemented. The new system incorporates a unique personal identifier to tie together each authorized person with the Signature Authorization File and the Chart of Accounts. The new system replaced the antiquated and unreliable name-based Signature Authorization system which had been in use since 1983. This on-line system is also used at the General Purchasing Office for screening incoming "paper" requisitions to verify approval signatures. It is also used for this purpose at other purchasing locations, the Office of Laboratory Supplies, Graphic Arts, Physical Plant, and the Microcomputer Center, and at the Comptroller's Accounting Office to verify approval signatures on invoices and request for payment and travel forms.
- (3) The Office of Laboratory Supplies commenced investigation into the utilization of barcode technology in its stockrooms to improve customer service and data entry accuracy. Barcode scanners are expected to be installed in all stockrooms by the fall of the coming year.
- (4) The Office of Laboratory Supplies (OLS) commenced development of a prototype electronic data interchange subsystem. The system will completely automate the procurement function through computer-to-computer purchase order placement between OLS and vendor computers.
- (5) Participation with the Environmental Medical Service and the Safety Office continued in the investigation, planning, and development of (i) controls, reporting, and tracking mechanisms for hazardous substance purchases, and (ii) purchasing methods and procedures to ensure compliance with Federal, State, and local government regulations and MIT policies. During the coming year this effort will result in the development and implementation of appropriate reporting mechanisms to facilitate the tracking of hazardous substances.

General Purchasing Office

Purchasing activity for the year continued at the previous year's level. Of a total 87,000 purchase orders issued by all on-campus purchasing agencies, the General Purchasing Office processed and issued 59,000 or 68 percent of the total.

Since a primary responsibility of this office is the purchase of required goods 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 of Laboratory Supplies processed and filled 78,000 requisitions containing 243,000 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 1.0 percent over the previous year. Sales of office and laboratory items increased 3.2 percent and sales of furniture and furnishings decreased 9.6 percent.

Established systems for receiving, storage, and delivery continued to be utilized to support the Microcomputer Center's personal computer resale programs.

Minority and Woman-Owned Business Purchasing Programs

Business placed Institute-wide under these affirmative action procurement programs resulted in the award of over \$14.0 million to minority and woman-owned business concerns. Over \$6.0 million was awarded to 338 minority businesses and over \$8.0 million was awarded to 698 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 60 active Subcontracting Plans under Institute Federal contracts which necessitated the submission of over 200 separate reports of accomplishments to Federal sponsors. Additionally, in order to provide guidance and assistance to principal investigators, over 200 internal progress reports were issued.

BARRY ROWE

Office of Registration and Student Financial Services

Several significant events can be recorded for the past year.

In the Bursar's Office, a second video tape has been developed and produced, in conjunction with the Center for Advanced Engineering Study. This one is entitled "Student Loans: An Investment in Your Future," and was shown to all first-time MIT loan recipients as part of a federally-required loan counseling process. (The earlier film, produced last year and entitled "Repaying Your Student Loans: A Decade of Working Together," is shown to borrowers as they leave the Institute, as part of the federally-mandated "exit interview" procedure.) Through innovative means such as these, and others, MIT's default rate on Perkins/National Direct Student Loans (NDSLs) improved from 2.2 percent in 1988 to 1.8 percent in 1989, and from 2.4 percent to 2.2 percent on Stafford Student Loans (formerly called GSLs and FISLs). The national default rates on these programs were 6.8 percent and 14.7 percent in 1989, respectively.

In the Registrar's Office, a request for funds was granted by the Administrative Systems Steering Committee to proceed with the first phase in the development of a new Student Information System. This phase is now essentially completed. The first steps were to prepare a comprehensive Requirements Definition and to complete a preliminary conceptual process model for the new system. Coopers and Lybrand was selected to review this work and to assist with the preparation of an implementational strategy. The pertinent analyses and the implementation plan are within weeks of completion, and we will return to the Steering Committee mid-summer for their review and approval of funding necessary to support the detail design of the new system, to be brought on line about three years hence.

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, a likely result as long as MIT's costs rise faster than inflation. Moreover, we have seen the third consecutive year in which the percentage has increased of needy freshmen in the class coming from the lowest national income quartile. These percentages over the last five years have been 11.8, 14.3, 20.2, 21.9, and 22.6; and demonstrate the gradual achievement of a goal long sought by the Institute—the growing accessibility of MIT to young people from the lowest income families. In order to sustain this growth, and in light of the continuing decrease in the effectiveness of the federal programs of financial support for students, we received a commensurate increase in the funds allocated to us by the Institute for this purpose.

In September the Institute, along with some 60 other colleges and universities, received a Civil Investigative Demand from the U.S. Justice Department. According to the text of the Demand, it was generated as a vehicle to help the Justice Department understand whether colleges might be in violation of national anti-trust legislation, as they set their tuition levels, their financial aid awards, and their faculty salaries. As part of MIT's response to the Demand, we were required to provide the Department with nearly 4,000 pages of file documents relative to our provision of financial aid during the five-year period from 1985 through 1989. No conclusions resulting from the Demand have yet been announced.

These events and accomplishments are discussed in further detail, and others mentioned, in the individual reports that follow from the Bursar, Registrar, and the Director of Student Financial Aid.

JACK H. FRAILEY, Director

BURSAR'S OFFICE

Student Services

- We improved our sponsored billing process, gaining greater accounting control and improving cash flow. We automated manual tasks, improved communications with sponsors, and decentralized responsibility for sponsored billing to ensure continuous coverage.

- Related to the MIT's Parent Loan Plan (PLP), which was established in 1977, we clarified legal and policy issues for the future, including co-applicant requirements, eligibility of Canadian citizens, allowance for possible future termination of the program, possible future assessment of late fees, and the ability to review credit bureau information of applicants. We improved our informational mailing to admitted freshmen.

- We implemented new telecommunications technologies (voice mail, traffic studies, and telephone routing trees) in our Student Services section to improve management of telephone calls.

- Student refund checks are now issued immediately, thanks to the cooperation of the Comptroller's Accounting Office.

Student tuition, fees, and other charges totaling \$159,804,659 were billed, an increase of 9.7 percent from last year. Servicing the 18,711 student accounts required 211,898 transactions to the student accounts receivable system. Income from late payment fees was \$141,613 and income from finance charges was \$194,125.

The PLP is an important source of funding for 294 families with active PLP accounts, of which 25 are new borrowers this year. A total of \$1,357,920 was disbursed during the year and \$1,837,944 in principal was collected. The PLP receivable at the end of the fiscal year was \$1,911,956. The default rate for the Parent Loan Plan (calculated as of June 30, 1990 using the formula for NDSL/Perkins Loans) is 0.4 percent.

The total student population supported by a sponsor (government, military, etc.) for the academic year 1989-90 was 901 students, representing total billings to sponsors of \$7,359,325.

Alumni Services

- We developed and produced a videotape (in conjunction with the MIT Center for Advanced Engineering Study) entitled "Student Loans: An Investment in Your Future." The video was shown to all first-time MIT student loan recipients and is part of a federally-required "loan counseling" process.

- In conjunction with MIT's legal counsel, Palmer & Dodge, a Collection Services Agreement was developed and signed by all agencies that collect delinquent student loans.

- We implemented credit bureau reporting for past due Technology Loans. We reduced past due loan accounts (number and dollars) and default rates.

Student loans receivable totaled \$44,414,565 at fiscal year end. These notes were funded by \$12,538,406 of MIT loan funds established by friends and alumni of the Institute; \$21,400,562 of federal funds in support of the Perkins (formerly the National Direct Student) Loan Program; \$51,856 of federal funds borrowed to support a portion of our contribution to the Perkins Loan Program; \$7,323,741 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 1.8 percent in 1989 (compared to 2.2 percent in 1988); the national default rate for that program decreased from 7.2 percent in 1988 to 6.8 percent in 1989. MIT's default rate on Stafford Student Loans (formerly called GSLs and FISLs) was 2.2 percent in 1989 (compared to 2.4 percent in 1988); the corresponding national default rate increased from 13.3 percent in 1988 to 14.7 percent in 1989.

Accounting and Information Systems

- We are using MIDAS and CMS to reconcile clearing accounts and are consolidating the office's accounting, financial, and information system functions.

- We expanded our use of personal computers, using them to automate manual procedures.

- We completed our analysis of the existing Student Accounts Receivable (SAR) system, implemented several upgrades to the current system and its interfaces with other systems, wrote specifications for a new system, and started the process of hiring an Analyst/Programmer to support our development and implementation of a new state-of-the-art SAR system.

- We completed a critical functions study for the MIT/Disaster Recovery project.

- We improved our use of personal computers with desktop publishing of most of our office's forms and brochures, and with bulk mailing of personalized collection letters. With these tools, we enhanced our communication and lowered our design and typesetting costs.

Staff Notes

Carlene Chisom-Freeman, Assistant Bursar/Loan Programs Administration, was named a "1990 Black Achiever" by the Greater Boston YMCA.

This has been a year of relatively little staff turnover compared to recent years:

- Ann Chick, Assistant to the Bursar/Student Services, left in September to become Administrative Assistant in Ocean Engineering.
- Jolanda Scott joined our staff as Assistant to the Bursar/Accounting and Control in August. She came from the Comptroller's Accounting Office where she was Staff Accountant.
- Sue-Yi Wang joined our staff as Assistant to the Bursar/Student Services in November. She came from Crosby Vandenberg Group of Boston where she was Assistant Production Manager, Computer and Composition Services.

Professional development of the staff was a high priority this year:

- Cheryl Blankenship, Sandra Chauncey, Florent Lebongo, and Kate Wilson were teachers in the Financial Operations "Individual Development Planning" program. Peter Brown and Ann Reilly taught in-house training sessions for Bursar's Office staff members on Microsoft Word, Excel, FileMaker, and electronic mail.
- Ms. Blankenship, Shirley Picardi, and Ms. Reilly served as advisors to MIT freshmen, and Mr. Brown and Ms. Chauncey were readers in the undergraduate admissions process. Janet Fischer completed a part-time, one semester internship in the International Students' Office.
- Ms. Chauncey and Ms. Wilson serve on the newly-formed First Wachovia Advisory Group. Ms. Wilson is also chair of the legislative committee of Coalition of Higher Education Assistance Organizations (COHEAO) and moderated a panel at the COHEAO conference. Mr. Brown serves as a member of the editorial board of College Users of Machine Records (CUMREC) and presented an office automation workshop at a meeting co-sponsored by MIT and Apple Computer. Ms. Picardi published two professional papers in *NACUBO Business Officer* and *MIT Management*.

SHIRLEY M. PICARDI, Bursar

REGISTRAR'S OFFICE

Enrollment

In 1989-90 student enrollment was 9,536, compared with 9,500 in 1988-89. This total was comprised of 4,307 undergraduates (compared with 4,325 the previous year), and 5,229 graduate students (compared with 5,175 the previous year). Undergraduate enrollment will continue to grow over the next several years as a result of the Institute's decision to increase the freshman class size from 1,000 students to about 1,050 beginning September 1989. The International student population was 2,044, representing eight percent of the undergraduate and 32 percent of the graduate populations. These students were citizens of 102 countries. Students with permanent resident status are included with U.S. citizens.

In 1989-90, there were 2,519 women students (1,460 undergraduate and 1,059 graduate) at the Institute, compared with 2,429 (1,412 undergraduate and 1,017 graduate) in 1988-89. In September 1989, 349 first-year women entered MIT, representing 33 percent of the freshman class.

In 1989-90, there were, as self-reported by students, 1,798 minority students (1,449 undergraduate and 349 graduate) at the Institute, compared with 1,637 (1,331 undergraduate and 306 graduate) in 1988-89. Minority students included 350 Black Americans (non-Hispanic), 25 Native Americans, 394 Hispanic Americans, and 1,029 Asian Americans. The first-year class entering in September 1989 included 421 minority students, representing 40 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1989-90 included 1,101 bachelor's degrees, 1,087 master's degrees, 36 engineer's degrees, and 509 doctoral degrees—a total of 2,733 (compared with 2,794 in 1988-89).

Tabular Presentation

Most of the above 1989-90 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: undertaking a variety of special efforts to achieve a smooth transition for the first Class (Class of 1990) graduating this year under the new undergraduate degree requirements (significant communication/counseling efforts with students and faculty/departments, modification of the undergraduate degree audit and procedures, and addressing exceptions to the new degree requirements in a year of transition); revising the Undergraduate and Graduate Term Summaries to reflect the above, as well as other improvements; assisting the work of various Faculty Committees (e.g., in finalizing an evening exam policy, formalizing into Faculty Regulations changes in the freshman Pass/No Record grading system to require "C" or better performance, and examining issues relating to disparities between credit units assigned to subjects and the typical amount of work done by students); fulfilling a wide variety of requests for information and statistics; linking recitation sections between freshman calculus and physics; negotiating the inclusion of grades received by MIT graduate students at Harvard on the MIT transcript (to the closest equivalent grade);

Implementing procedures to expedite timely completion of the Writing, HASS Concentration, and Physical Education Requirements by seniors, and providing these offices with electronic capabilities to monitor and maintain the status of students in completing these requirements; supporting the efforts of Network Services at MIT to provide the Academic Calendar, Catalogue Subject Descriptions, Class Schedules, etc. on the campus network; providing major leadership in updating policies and procedures in the Guide for Undergraduates and Faculty Advisors; continuing the development of a policy in the event of a snow closing during Final Exam week; initiating efforts to get more departments to have terminal visibility to academic data on the student system; implementing the new HASS-Distribution requirements; implementing an informal IAP registration procedure to respond to the substantial increase in the number of subjects giving academic credit during IAP; working with an ad hoc group centered in the ODSA to clarify policies and procedures for releasing information from the student data base; implementing procedures to recognize the first large group of students—a total of 120—who earned HASS Minors this year;

Opening a satellite Registrar's Office in the main building corridor to more effectively provide services to students; proposing new grade notations to address inequities and inconsistencies in the current grading system (when students fail to officially cancel a subject registration, and when no grade is submitted by the instructor); working with the Planning Office and Dean for Undergraduate Education to prepare an analysis of priorities for a classroom/lecture facilities renovation plan for the next several years; installing a plaque in each classroom identifying whom faculty should contact if something needs repair; developing procedures with Physical Plant to give high priority to classroom maintenance requests; and working with an ad hoc faculty group to develop, as well as gain Faculty approval of, a calendar proposal to extend the Final Examination Period to five days each term and to lengthen the Reading Period in the spring term.

•Strengthen effectiveness in administrative procedures and office operations: improving the physical working environment in the Registrar's Office by the addition of carpeting throughout the office and new furnishings for the office's reception/student service area, and resubmitting a proposal for moving the entire Registrar's Office back to the main building; initiating a series of discussions with Dean Jacqueline Simonis in the ODSA to share experiences on how particular difficult situations are handled, as part of staff development; initiating biweekly section meetings in the Records and Registration Sections; provision of greater hospitality services on Registration Day and other deadline days; changing policy on tuition rates for special students in Summer Session; developing a full algorithm for the academic calendar; taking full responsibility for preparing camera-ready copy for the Subject Descriptions Chapter of the MIT catalogue (half of the book); implementing procedures for withholding registration for students who have not fulfilled immunization requirements; substantially simplifying the procedures for cross-registering students into

MIT's ROTC programs; working with the Secretary of the Faculty to discontinue sending Degree Recommendation letters to students (to focus the effort on those removed from the Degree List by the Faculty); and documenting the procedures in various sections in the Registrar's Office.

•Make improvements to the current Student Information System and Registrar's Office PC network: completing development of the new database system on the PC network for updating catalogue subject descriptions and disseminating subject and curricular information to various offices/departments; completing the development of programs to do Commencement Book and diploma processing on the PC network; developing an interface to pass Student Directory information to Project Athena for the electronic directory; making modest progress in rewriting GASP into C language (a joint effort with Bentley College that is well behind schedule because of lack of time availability of Bentley staff); correcting errors in the backup/restore processing and in Grade Panels; participating in the development of a disaster recovery plan for critical functions of the SIS; undertaking programming that restricts departmental visibility on the SIS to their own students (including multiple majors); assisting the Medical Department in modifying their BC/BS interface; refining the assessment of those expected to register next term, to assist in student billing; supporting monthly user meetings of staff from all areas using the SIS for the purpose of information exchange and coordination of operations, training on system functionality, and discussion of issues that relate to the development of the new computer system; and making substantial improvements in the local area PC network to assist with development of the new SIS.

•Undertake major effort to develop a new Student Information System: As a result of a proposal that was prepared last summer, the Registrar's Office was given support from the Administrative Systems Steering Committee to undertake the first phase in the development of a new Student Information System (SIS). The need for a new computer system was based in part upon the findings of a "business analysis" that was undertaken last year, which indicate that the 17 year-old system is complex and expensive to maintain, and not an effective base from which to address problems with the current system and to expand the types and levels of service needed by the academic programs and administrative services at MIT. The new student system will have on-line interactive editing and updating, and distributed access to students, departments, and faculty. It was decided to continue running under OS/VS1 so that resources can then be directed toward development of the new system over the three- to four-year period; OS/VS1 conversion appears to be expensive and risky—and once finished, results in just a converted old system.

•Accomplishments in the first phase of the development process include: completing a survey of the existing system to document current operating procedures and functions; hiring contract programmers to help maintain the current system; conducting approximately 100 interviews with users of the SIS (administrative offices, as well as faculty and staff departmental administrators); convening a student advisory group; convening a faculty advisory group to help examine fundamental assumptions used in administering MIT's academic programs; preparing a robust Requirements Definition for the new system—describing in broad outline what we want the new system to do in supporting MIT's academic and administrative programs; completing a preliminary conceptual process model of the new SIS; issuing a Request for Qualifications from software vendors of student systems; selecting Coopers and Lybrand to review the Requirements Definition and provide assistance with preparation of an implementation strategy; developing an Information Policy to control visibility to academic information on the system; and preparing the first draft of an implementation strategy—including evaluation of software packages to determine their capabilities to satisfy our requirements, investigation of technologies to increase automation, high-level project plan, staffing plan to make optimal use of MIT resources/capabilities, and cost/benefit analysis. Once the analysis is finished and an implementation plan is developed (modifying a package versus custom development), we will return to the Steering Committee in July for review of the project and approval of funding for implementing the new system, which would then be installed starting in about three years.

Important Issues on the Agenda

•Move forward to complete the development of a new Student Information System. Make provisions to maintain/improve the current system during the development period.

•Strengthen the academic research capabilities in the Registrar's Office in support of the Institute's educational programs.

•Continue to develop various ways of passing data electronically between the Registrar's Office and faculty/departmental offices; establish more departments with terminal visibility to the system for their students and subjects and provide training sessions for academic administrators.

- Develop enhancements that make the GASP scheduling system more flexible and responsive to faculty and departmental needs. Establish a computerized room scheduling book on the PC network. Develop an effective way to schedule Final Exams over the 10 exam periods now provided in the calendar, so that the schedule can be announced close to Registration Day.
- 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. In the meantime, continue to strengthen the operations and effectiveness of the Registrar's Satellite Office in the main building.
- Continue to streamline the audit of the new undergraduate degree requirements. Implement the changes made by the Faculty in Pass/Fail grading.
- Develop an electronic certification process so that students and alumni can get faster, more complete official letters providing information about their attendance at MIT. Develop an electronically prepared transcript.
- Develop with the Institute Archivist a clear written archival policy for the retention and protection of student records at MIT, and a clear written policy for the release of transcript information.
- Undertake career development efforts to help develop the leadership, communication, and management skills of staff and support staff.

Staff Notes

Robert Principato joined the office as Manager of the Student Information System and Associate Registrar, and has done a remarkable job during his first year in helping the student service areas that use the SIS move toward development of a new Student Information System.

Tom McCormack, who began as a student programmer in the office a decade ago and eventually became a staff member, received the S.B. degree in Management Science from MIT this June.

DAVID S. WILEY, Registrar

STUDENT FINANCIAL AID OFFICE

Confirming a Pattern

The year featured another increase in the number of needy students receiving aid; certainly solidifying the now well-established pattern of MIT's costs rising faster than inflation, and reflecting as well another year in which the percentage of the freshman class coming from the lowest national income quartile increased. Neither of these causative factors seems to be evanescent; so we must expect annual increases in the proportion of the undergraduate student body that requires some measure of financial aid.

As we have stated before, this increase is testimony to the growing accessibility of MIT to young people from lower-income families—a goal that the Institute has long sought; but a needier population will most certainly translate to the need for more funds for grants and scholarships.

The Need for Financial Aid

The aggregate undergraduate need for assistance grew again, by \$4,070,000. Eighty-five more needy students were assisted than last year, and the average need for help rose, by almost \$1,200, to \$14,500. In the aggregate, the financial aid program required \$17,672,000 from needy students' family resources, and provided \$35,883,000 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 an increase in grants from all three federal programs, bringing them up by eight percent; but the overall increase in the need for scholarships this year again resulted in the federal participation percentage figure dropping to 12.3 percent—again the lowest since the early 1960s. Another substantial increase was recorded in income from endowed scholarship funds, derived from additional gifts related to the Campaign for MIT, continued good investment performance by the portfolio, and effective use by the Aid Office of the available dollars. Scholarship awards made directly to needy students by outside sponsors rose again, exceeding the \$2 million mark. Overall, the level of awards from designated grant and scholarship resources reached \$14.4 million; and was 21 percent higher than last year. But these resources once again fell far short of the need, and the program was augmented by \$9,553,000 from unrestricted income, a figure that represents about 15 percent of undergraduate tuition income. The New MIT Opportunity Grants Program accounted for just under \$500,000 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)

<u>Source</u>	<u>1987-88</u>	<u>1988-89</u>	<u>1989-90</u>
Pell Grants	\$ 665,000	\$ 837,000	\$ 931,000
SEO Grants	1,317,000	1,235,000	1,356,000
ROTC Scholarships	565,000	670,000	670,000
Scholarship Endowment	5,379,000	6,410,000	8,295,000
Current Gifts	1,036,000	821,000	1,088,000
Direct Grants	1,918,000	1,971,000	2,058,000
Unrestricted Funds [¶]	6,969,000	8,549,000	9,553,000
Total Grants Awarded	\$17,849,000	\$20,493,000	\$23,951,000

* 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.

[¶]Including MIT Opportunity Awards and Special Program Grants.

Loans

The year marked a reversal in last year's borrowing phenomena, with undergraduates borrowing more and graduate students borrowing less this year than last. At the undergraduate level, awards from the Technology Loan Fund again increased, reaching just over \$1 million; and the loans obtained from banks under the Stafford Loan Program increased to \$4.5 million. There was less available to lend in the Perkins Loan Fund—the maximum award to each eligible student had to be set at only \$1,700.

For a third 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 Stafford Loan program; both MIT's involvement in the program and that of the commercial sector were diminished from last year.

The following table details loan use by undergraduate and graduate students:

Loans

(received by needy and non-needy students)

<u>Source</u>	<u>1987-88</u>	<u>1988-89</u>	<u>1989-90</u>
A. <u>Awarded to Undergraduates</u>			
Technology Loan Fund	\$ 735,000	\$ 912,000	\$ 1,151,000
Perkins/National Direct Loans	2,478,000	3,633,000	3,196,000
Stafford Student Loans	5,068,000	3,495,000	4,572,000
Sub-Total	\$8,281,000	\$8,040,000	\$8,919,000
B. <u>Awarded to Graduate Students</u>			
Technology Loan Fund	\$1,311,000	\$2,066,000	\$2,552,000
Stafford Student Loans by Commercial Lenders	3,473,000	3,721,000	3,467,000
Stafford Student Loans by MIT	594,000	691,000	343,000
Sub-Total	\$5,378,000	\$6,478,000	\$6,362,000

Work Programs

The off-campus job market showed a 10 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. The number of students working on campus showed no change.

The College Work-Study Program allocation again increased slightly above the 1988-89 level and was used entirely to subsidize the on-campus student employment program. Approximately half of the total 1989-1990 allocation was used to subsidize undergraduate work, and half to subsidize graduate student teaching assistantships.

The funds we receive from the Massachusetts Educational Employment Program, though small, remain important to MIT. One recipient, who was graduated in February, epitomizes the need for such programs. This student overcame personal and financial strife over ten years to matriculate. During the last two years, MEEP funds allowed her to find interesting, academically related employment and be compensated well enough to allow her to pay for her education while keeping her considerable debt from escalating.

The Student Employment Office created a "job board" database on the Macintosh. The file was designed to provide us with a vehicle 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

•During the spring term, after hearing the results of several years of discussion and research, the MIT Academic Council approved a change in the way the SFAO responds to a scholarship received from an agency outside of MIT, when the recipient has already received a grant commitment from MIT. The following policy will take effect for the 1990-91 school year, in all four undergraduate classes:

The receipt of an outside scholarship will in most cases now allow the student to increase his/her total scholarship and grant award and reduce the self-help expectation. As a general rule, 40 percent of the value of all eligible scholarships will be used to reduce self-help [Perkins and Stafford loans and work expectation (CWSP)]. Only the remaining 60 percent of the value of these awards will reduce the amount of MIT grants

originally awarded, rather than 100 percent as the prior policy required. This welcome change was catalyzed in 1985 by the Faculty Committee for Undergraduate Admissions and Financial Aid (CUAFA), and consummated in the spring in response to a proposal by the Student Financial Aid Office.

•The year marked the provision of the third 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 three classes in September 1990, holding these awards. The SFAO made Opportunity Awards to 80 of the new freshman class; there will be approximately 235 sophomores and juniors in the program as well. These students are enjoying a significant reduction in the standard "self-help" (loan and job) expectation.

•The Office entered the Student Information System upgrade project in a major way this year; our contribution was a complete definition of the financial-aid processing and reporting requirements we need for the data-processing system that will likely bring us through the '90s.

•The SFAO is putting its network of Macintosh computers to good use in preparing our publications. During the year we made the transition, for three of our periodic documents, from full dependence on outside help for page-makeup, to in-house design and layout using two Macintosh software programs. In addition to some savings in out-of-pocket costs, we are hoping to improve turn-around times significantly by making this change as thorough-going as we can.

•The Office participated in the program of MIT's Parents' Weekend in October, by preparing and delivering a slide-reinforced presentation of salient facts about the MIT financial aid program. The attendance level and character of the questions asked during the presentation suggests that the needs of parents will be best served by a more informal "open house" arrangement in the Office during future on-campus programs.

Staff Notes

During the year Analyst/Programmer Steven T. Nalesnik left the SFAO to begin new employment as a software programmer/designer in Pennsylvania.

Collins Mikesell was appointed to the staff in June, to assume the duties of this important systems-management position. Mr. Mikesell was graduated with a Bachelor of Science degree in math and physics from Lebanon Valley College in 1979, and held several positions related to computer systems in the business world before coming to MIT.

Donna Kendall, who joined the SFAO support staff in 1984 as receptionist, and was promoted to the administrative staff in 1987, recently received the B.A. degree in History from Boston College.

LEONARD V. GALLAGHER, Director

NUMBER OF STUDENTS BY COURSE AND YEAR, 1989-90*

	1	2	3	4	Grad	Grad Non-Res	Grand Total	Course Number
SCHOOL OF ARCHITECTURE AND PLANNING								
Architecture, IV		31	40 (1)	45	263 (8)	12	391 (9)	IV
Architecture, IV-B		-	4	2	-	-	6	IV-B
Urban Studies and Planning, XI		-	3	2	165 (10)	26	196 (10)	XI
Total		31	47 (1)	49	428 (18)	38	593 (19)	Total
SCHOOL OF ENGINEERING								
Aeronautics and Astronautics, XVI		77	83	92 (1)	226 (12)	-	478 (13)	XVI
Aeronautics and Astronautics, XVI-B (Cooperative)		-	-	3	-	-	3	XVI-B
Aeronautics and Astronautics, XVI-C (Internship)		-	10	12	-	-	22	XVI-C
Chemical Engineering, X		60	45	35	220 (5)	4	364 (5)	X
Chemical Engineering, X-C		1	2	2	-	-	5	X-C
Civil Engineering, I		10	26	18	264 (6)	3	321 (6)	I
Civil Engineering, I-A		17	16	13	-	-	46	I-A
Civil Engineering, I-W (Woods Hole)		-	-	-	2	-	2	I-W
Electrical Engineering and Computer Science, VI		-	-	-	607 (57)	-	607 (57)	VI
Program 1-Electrical Science and Engineering		182	109 (1)	128 (1)	-	-	419 (2)	VI-1
Program 3-Computer Science and Engineering		84	63	76 (1)	-	-	223 (1)	VI-3
Electrical Engineering and Computer Science, VI-A (Cooperative)		-	-	-	124 (3)	-	124 (3)	VI-A(Co-op)
Program 1-Electrical Science and Engineering		-	55	58	-	-	113	VI-1(Co-op)
Program 3-Computer Science and Engineering		-	24	26	-	-	50	VI-3(Co-op)
Electrical Engineering and Computer Science, VI-W (Woods Hole)		-	-	-	3	-	3	VI-W
Materials Science and Engineering, III		32	11 (1)	18 (1)	190 (7)	3	254 (9)	III
Materials Science and Engineering, III-A		-	-	2	-	-	2	III-A
Materials Science and Engineering, III-B (Internship)		7	29	28	-	-	64	III-B
Mechanical Engineering, II		134	133	126	426 (26)	-	819 (26)	II
Mechanical Engineering, II-A		17	10	12	-	-	39	II-A
Mechanical Engineering, II-B (Internship)		-	19	31	-	-	50	II-B
Mechanical Engineering, II-W (Woods Hole)		-	-	-	2	-	2	II-W
Nuclear Engineering, XXII		4	6	12	150 (1)	-	172 (1)	XXII
Nuclear Engineering, XXII-A (Internship)		-	2	2	-	-	4	XXII-A
Ocean Engineering, XIII		3	2	4	77 (5)	-	86 (5)	XIII
Ocean Engineering, XIII-W (Woods Hole)		-	-	-	23	-	23	XIII-W
Naval Construction and Engineering, XIII-A		-	-	-	37	-	37	XIII-A
Ocean Systems Management, XIII-B		-	-	-	12	-	12	XIII-B
Center for Advanced Engineering Study, EN		-	-	-	67 (67)	-	67 (67)	EN
Total		628	645 (2)	698 (4)	2,430 (189)	10	4,411 (195)	Total
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE								
Economics, XIV		23 (1)	40	36	132 (2)	8	239 (3)	XIV
Anthropology/Archaeology, XXI-Y		1	-	-	-	-	1	XXI-Y
History, XXI-H		-	-	2	-	-	2	XXI-H
Literature, XXI-L		2	2	1	-	-	5	XXI-L
Music and Theater Arts, XXI-M		-	2	-	-	-	2	XXI-M
Writing Program, XXI-W		2	2	3	-	-	7	XXI-W
Humanities, XXI-D, XXI-P		-	-	1	-	-	1	XXI-D, XXI-P
Humanities and Engineering, XXI-E		-	3	4	-	-	7	XXI-E
Humanities and Sciences, XXI-S		-	1	11	-	-	12	XXI-S
Linguistics and Philosophy, XXIV		1	3	5	70 (3)	4	83 (3)	XXIV
Political Science, XVII		16	9	17	132 (5)	35	209 (5)	XVII
Program in Science, Technology, and Society, XXI-T, STS		-	-	-	10 (1)	-	10 (1)	XXI-T, STS
Total		45 (1)	62	80	344 (11)	47	578 (12)	Total
SLOAN SCHOOL OF MANAGEMENT								
Management, XV		32	44	52	490 (21)	10	628 (21)	XV
Management Fellows, XV-A		-	-	-	67 (11)	-	67 (11)	XV-A
Management-Operations Research, XV-B		-	-	-	24	-	24	XV-B
Management-Ph.D., XV-P		-	-	-	76	-	76	XV-P
Total		32	44	52	657 (32)	10	795 (32)	Total
SCHOOL OF SCIENCE								
Program in Applied Biological Sciences, XX		-	-	-	30	-	30	XX
Biology, VII		75	87	52	183 (8)	-	397 (8)	VII
Biology, VII-A		3	11	16	-	-	30	VII-A
Biology, VII-B		-	-	5	-	-	5	VII-B
Biology, VII-W (Woods Hole)		-	-	-	19	-	19	VII-W
Chemistry, V		27	23	32	261 (2)	3	346 (2)	V
Earth, Atmospheric, and Planetary Sciences, XII		5	8	14	110 (2)	1	138 (2)	XII
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)		-	-	-	65	-	65	XII-W
Mathematics, XVIII		26	30	44	117 (7)	8	225 (7)	XVIII
Mathematics with Computer Science, XVIII-C		19	8	27	-	-	54	XVIII-C
Physics, VIII		58	51	54 (1)	305 (3)	1	469 (4)	VIII
Physics, VIII-A		10	15	14	-	-	39	VIII-A
Total		223	233	258 (1)	1,090 (22)	13	1,817 (23)	Total
WHITAKER COLLEGE of Health Sciences and Technology								
Brain and Cognitive Sciences, IX		15	11	15	51 (1)	-	92 (1)	IX
Health Policy and Management, HPM		-	-	-	2	-	2	HPM
Toxicology, TOX		-	-	-	22	-	22	TOX
Total		15	11	15	75 (1)	-	116 (1)	Total
Harvard-MIT Division of Health Sciences and Technology, HST								
		-	-	-	87 (66)	-	87 (66)	HST
Undesignated								
		70	22 (22)	-	-	-	92 (22)	Undesignated
First Year								
	1,047	-	-	-	-	-	1,047	First Year
Grand Total								
	1,047	1,044 (1)	1,064 (25)	1,152 (5)	5,111 (339)	118	9,536 (370)	Grand Total
Not included in above totals:								
Foreign Study: 2 students in the third year, 3 students in the fourth year, 1 student in the fifth year. Domestic Study: 1 student in the second year, 3 students in the third year.								
Non-Institute Harvard	20	32	30	31	197	-	310	NIH
Non-Institute Tufts	17	17	23	13	-	-	70	NIT
Non-Institute Wellesley	6	31	38	46	-	-	121	NIW
*All figures include special students (special students also shown separately in parentheses)								

ACADEMIC STAFF COUNT

	Professors*	Administration and Professors*	Institute Professors Emerit Part Time*	Adjunct Professors*	Associate Professors*	Assistant Professors*	Sr. Lecturers and Professors Emerit*	Sr. Lecturers	Lecturers	Sr. Research Scientists	Instructors	Technical Instructors	Sr. Research Associates	Postdoctoral Associates	Research Assistants	Teaching Assistants	Instructor Grad	Total	Visiting Professors	Other†
INSTITUTE PROFESSORS	9	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	1	-
SCHOOL OF ARCHITECTURE AND PLANNING																				
Architecture	10	2	-	-	7	7	1	-	17	-	1	1	-	-	27	61	-	134	1	6
Urban Studies and Planning	13	1	-	2	6	3	3	3	6	1	-	-	-	-	46	5	1	90	1	18
Media Arts and Sciences Sect.	3	1	-	1	4	4	-	-	-	-	-	-	-	-	78	-	-	91	4	3
Total	26	4	-	3	17	14	4	3	23	1	1	1	-	-	151	66	1	315	6	27
SCHOOL OF ENGINEERING																				
Aeronautics and Astronautics	-	-	-	-	3	-	1	-	1	-	-	-	-	-	-	-	-	5	-	-
Chemical Engineering	18	3	-	3	7	6	5	3	10	-	-	3	-	2	178	10	2	250	1	10
Civil Engineering	21	3	-	-	3	4	1	1	1	-	2	1	1	14	173	29	-	254	-	37
Electrical Engineering and Computer Science	22	4	-	-	7	5	-	1	2	-	1	-	-	7	176	26	2	253	4	17
Materials Science and Engineering	57	15	-	5	28	14	9	-	10	2	-	4	-	1	466	103	2	716	2	17
Mechanical Engineering	15	5	-	2	10	5	5	1	1	-	-	2	1	14	157	19	1	238	3	29
Nuclear Engineering	28	1	-	1	18	10	7	9	30	1	-	6	1	12	305	27	1	457	6	30
Ocean Engineering	15	2	-	-	2	3	-	-	1	2	-	-	-	1	101	18	-	145	-	16
Program in Technology and Policy	13	1	-	-	7	-	1	2	9	-	-	-	-	6	61	11	1	112	1	6
Total	189	34	-	11	85	47	29	17	65	5	3	16	3	57	1,619	243	9	2,432	17	162
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																				
Economics	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2	-	1
Anthropology/Archaeology	18	2	-	-	3	6	-	-	-	-	-	-	-	1	9	27	-	66	3	11
Foreign Languages and Literatures	3	1	-	-	1	2	-	-	2	-	-	-	-	-	-	-	-	9	-	1
History	4	-	-	-	4	1	-	1	16	-	-	-	-	-	-	-	-	26	3	1
Literature	4	2	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	11	3	-
Music and Theater Arts	9	2	-	-	3	1	-	-	5	-	1	-	-	-	-	-	-	21	-	-
Writing Program	6	2	-	-	2	1	-	3	11	-	-	4	-	-	-	-	-	29	-	10
Linguistics and Philosophy	3	1	-	1	2	2	-	1	13	-	-	8	-	-	-	-	-	31	-	6
Political Science	12	2	-	-	3	3	-	-	-	-	-	-	-	-	11	11	-	42	1	13
Program in Science, Technology, and Society	14	2	-	1	4	3	-	-	3	-	-	-	-	-	35	17	1	80	1	2
Total	79	15	-	2	27	22	-	5	51	-	1	13	1	2	61	56	1	336	12	65
SLOAN SCHOOL OF MANAGEMENT																				
Management	35	3	-	3	20	22	2	9	5	-	-	-	1	-	88	63	1	252	15	21
SCHOOL OF SCIENCE																				
Biology	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Chemistry	30	3	-	-	12	8	2	1	-	-	3	1	-	55	31	-	-	146	1	81
Earth, Atmospheric, and Planetary Sciences	24	2	-	-	4	2	2	-	-	1	-	1	-	54	187	58	-	335	-	75
Mathematics	23	2	-	-	9	4	1	1	-	2	-	-	-	13	131	14	-	200	6	29
Physics	37	1	-	-	7	9	1	1	3	-	22	-	-	1	43	50	1	176	2	22
Total	59	5	-	-	10	10	3	-	13	-	8	-	9	251	47	-	-	415	1	11
Total	174	13	-	-	42	33	9	3	3	16	25	10	-	132	643	169	1	1,273	10	218
WHITAKER COLLEGE OF HEALTH SCIENCES AND TECHNOLOGY																				
Brain and Cognitive Sciences	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	2	1	-
Toxicology	16	2	-	-	7	4	-	-	5	-	-	2	-	2	7	6	-	51	-	61
Total	2	2	-	1	-	1	-	-	1	-	-	-	-	10	19	-	-	36	-	14
Total	18	4	-	1	7	6	-	1	6	-	-	2	-	12	26	6	-	89	1	75

Administration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
Aga Khan Program in Islamic Architecture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	
Air Force Aerospace Studies	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	7	1	-	
Artificial Intelligence Laboratory	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	10	
Athletic Department	-	1	-	-	10	5	-	1	-	12	-	-	-	-	-	-	-	29	-	22	
Biotechnology Process Engineering Ctr.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	9	
Center for Advanced Engineering Studies	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	
Center for Advanced Visual Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	
Center for Cancer Research	-	-	-	-	-	-	-	-	-	-	-	-	23	-	-	-	-	23	-	76	
Center for Cognitive Science	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	
Center for Environmental Health Sciences	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	2	
Center for International Studies	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	21	
Center for Technology Policy and Industrial Development	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2	-	9	
Center for Materials Research in Archaeology and Ethnology	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	3	
Center for Materials Science and Engineering	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	4	
Center for Space Research	-	-	-	-	-	-	-	1	-	-	-	5	-	-	-	-	-	6	-	8	
Center for Transportation Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Clinical Research Center	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	5	-	29	
Concourse	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	
Division of Comparative Medicine	-	1	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	4	-	18	
Energy Laboratory	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	17	
Environmental Medical Service	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Experimental Study Group	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	1	
Francis Bitter National Magnet Laboratory	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	47	
Harvard-MIT Division of Health Sciences and Technology	2	-	-	-	2	1	1	1	6	-	1	3	66	2	-	-	-	85	3	35	
Haystack Observatory	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	
Laboratory of Architecture and Planning	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Laboratory for Computer Science	-	-	-	-	-	-	-	-	2	-	-	3	-	-	-	-	-	5	-	10	
Laboratory for Electromagnetic and Electronic Systems	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	
Laboratory for Information and Decision Systems	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	-	-	4	-	7	
Laboratory for Manufacturing and Productivity	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	2	-	6	
Laboratory for Nuclear Science	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2	-	23	
Materials Processing Center	-	-	-	-	-	-	-	-	1	-	-	8	-	-	-	-	-	9	-	14	
Media Laboratory	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	18	
Medical Department	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	155	
Military Science	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	7	-	-	
Naval Science	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	8	2	-	
Nuclear Reactor Laboratory	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	10	
Office of the Provost	2	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	4	-	2	
Operations Research Center	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	2	
Plasma Fusion Center	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3	-	16	
Project Athena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	
Research Laboratory of Electronics	-	-	-	-	-	-	-	1	-	-	-	8	-	-	-	-	-	9	-	59	
Sea Grant Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Spectroscopy Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	
Statistics Center	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	1	
Student Activities	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	5	-	1	
Total	4	4	-	-	12	5	1	1	5	14	18	28	2	74	68	2	-	238	6	715	
Grand Total	534²	77²	8²	20²	210²	149²	45²	39²	158²	36	48²	70²	7	277	2,656	605²	13²	4,952	68¹⁴	1,283³	
Faculty Ex Officio *																			26		
																				4,978	

*Total Faculty 1,069

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 1,976

³Not included in preceding total

⁴Visiting Professors include 34 Professors, 17 Associate Professors, 16 Assistant Professors, 1 Institute Professor.

Humanities and Science	-	2	12	-	-	-	-	-	-	-	-	-	-	-	-	2	12				
Linguistics	-	-	-	-	-	1	-	-	-	-	1	3	3	-	-	1	3	4			
Literature	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2			
Philosophy	-	1	4	1	-	2	-	-	-	-	-	1	6	-	-	1	2	12			
Political Science	1	1	18	1	8	10	-	-	-	-	3	8	3	-	-	5	17	31			
Total	4	6	94	2	8	13	-	-	-	-	9	17	24	-	-	15	31	131			
SLOAN SCHOOL OF MANAGEMENT																					
Management	-	-	-	5	29	233	-	-	-	-	3	4	9	-	-	8	33	242			
Management Science	3	8	40	-	-	-	-	-	-	-	-	-	-	-	-	3	8	40			
Total	3	8	40	5	29	233	-	-	-	-	3	4	9	-	-	11	41	282			
SCHOOL OF SCIENCE																					
Applied Biological Sciences	-	-	-	-	-	2	-	-	-	-	4	1	1	-	-	4	1	3			
Biochemical Engineering	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-			
Biology	-	-	-	1	1	2	-	-	-	-	5	4	10	-	-	6	5	12			
Undesignated	-	1	21	-	-	-	-	-	-	-	-	-	-	-	-	-	1	21			
Chemistry	-	5	26	-	-	5	-	-	-	-	12	26	8	-	-	12	31	39			
Earth and Planetary Sciences	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	1	1	2			
Earth, Atmospheric, and Planetary Sciences	1	1	17	-	-	-	-	-	-	-	5	8	4	-	2	6	9	23			
Life Sciences	2	5	47	-	-	-	-	-	-	-	-	-	-	-	2	5	47				
Mathematics	1	2	40	1	-	3	-	-	-	-	3	2	13	-	-	5	4	56			
Mathematics with Computer Science	-	3	15	-	-	-	-	-	-	-	-	-	-	-	-	-	3	15			
Meteorology	-	-	-	2	1	2	-	-	-	-	-	-	-	-	-	2	1	2			
Physics	3	6	59	-	3	3	-	-	-	-	14	6	12	-	1	17	16	74			
Total	7	23	225	5	7	19	-	-	-	-	43	47	48	-	1	2	55	78	294		
WHITAKER COLLEGE of Health Sciences and Technology																					
Cognitive Science	1	1	11	-	-	-	-	-	-	-	-	-	-	-	-	1	1	11			
Brain and Cognitive Sciences	-	-	-	1	1	-	-	-	-	-	6	1	2	-	-	7	2	2			
Toxicology	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1	-	1			
Health Policy and Management	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	3			
Total	1	1	11	1	1	-	-	-	-	-	7	1	6	-	-	9	3	17			
Harvard-MIT Division of Health Sciences and Technology																					
Medical Engineering	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	1	-	4			
Medical Physics	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1			
Management of Technology																					
Operations Research	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	40			
Operations Research	-	-	-	-	4	5	-	-	-	-	-	-	-	-	-	-	4	5			
Technology and Policy	-	-	-	4	5	17	-	-	-	-	-	-	-	-	-	4	5	17			
Transportation	-	-	-	2	3	6	-	-	-	-	-	-	-	-	-	2	3	6			
Without Course Specification	-	-	-	13	11	22	-	-	-	-	-	-	-	-	-	13	11	22			
Awarded Jointly with Woods Hole Oceanographic Institution																					
Biology	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	1	2			
Civil Engineering	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1			
Earth, Atmospheric, and Planetary Sciences	-	-	-	4	-	1	-	-	-	-	1	2	5	-	-	5	2	6			
Electrical Engineering and Computer Science	-	-	-	1	-	-	-	-	1	-	-	-	1	-	-	2	-	1			
Mechanical Engineering	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-			
Ocean Engineering	-	-	-	2	1	-	-	-	3	-	-	-	-	-	-	5	1	-			
Grand Total	37	103	961	161	200	645	2	15	63	7	6	23	143	145	185	11	13	12	361	482	1,889

584 Vice President for Financial Operations

NUMBER OF WOMEN STUDENTS BY COURSE AND YEAR, 1989-90¹

COURSE NAME	Year				G	Non-Res. ²	Grand Total	Course Number	
	1	2	3	4					
SCHOOL OF ARCHITECTURE AND PLANNING									
Architecture, IV		13	25	21	80 (4)	3	142 (4)	IV	
Architecture, IV-B		-	2	1	-	-	3	IV-B	
Urban Studies and Planning, XI		-	2	1	63 (1)	12	78 (1)	XI	
Total		13	29	23	143 (5)	15	223 (5)	Total	
SCHOOL OF ENGINEERING									
Aeronautics and Astronautics, XVI		23	18	20	22 (3)	-	83 (3)	XVI	
Aeronautics and Astronautics, XVI-C (Internship)		-	-	5	-	-	5	XVI-C	
Chemical Engineering, X		37	25	21	35 (1)	-	118 (1)	X	
Chemical Engineering, X-C		1	2	1	-	-	4	X-C	
Civil Engineering, I		3	9	6	48 (1)	-	66 (1)	I	
Civil Engineering, I-A		9	9	4	-	-	22	I-A	
Electrical Engineering and Computer Science, VI		-	-	-	101 (9)	-	101 (9)	VI	
Program 1-Electrical Science and Engineering		37	20	32	-	-	89	VI-1	
Program 3-Computer Science and Engineering		11	15	15	-	-	41	VI-3	
Electrical Engineering and Computer Science, VI-A (Cooperative)		-	-	-	19 (1)	-	19 (1)	VI-A(Co-op)	
Program 1-Electrical Science and Engineering		-	12	19	-	-	31	VI-1(Co-op)	
Program 3-Computer Science and Engineering		-	8	8	-	-	16	VI-3(Co-op)	
Materials Science and Engineering, III		18	4	6	52 (1)	1	81 (1)	III	
Materials Science and Engineering, III-B (Internship)		4	17	15	-	-	36	III-B	
Mechanical Engineering, II		34	28	37	55 (2)	-	154 (2)	II	
Mechanical Engineering, II-A		5	2	3	-	-	10	II-A	
Mechanical Engineering, II-B (Internship)		-	7	7	-	-	14	II-B	
Nuclear Engineering, XXII		1	4	2	15 (1)	-	22 (1)	XXII	
Nuclear Engineering, XXII-A (Internship)		-	1	2	-	-	3	XXII-A	
Ocean Engineering, XIII		1	-	1	10 (1)	-	12 (1)	XIII	
Ocean Engineering, XIII-W (Woods Hole)		-	-	-	1	-	1	XIII-W	
Naval Construction and Engineering, XIII-A		-	-	-	2	-	2	XIII-A	
Center for Advanced Engineering Study, EN		-	-	-	8 (8)	-	8 (8)	EN	
Total		184	181	204	368 (28)	1	938 (28)	Total	
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE									
Economics, XIV		13	11	17	30	-	71	XIV	
Music, XXI-M		-	1	-	-	-	1	XXI-M	
Writing, XXI-W		1	2	1	-	-	4	XXI-W	
Humanities, XXI-D, XXI-P		-	-	1	-	-	1	XXI-D, XXI-P	
Humanities and Engineering, XXI-E		-	2	1	-	-	3	XXI-E	
Humanities and Science, XXI-S		-	1	7	-	-	8	XXI-S	
Linguistics and Philosophy, XXIV		1	1	3	24 (2)	-	29 (2)	XXIV	
Political Science, XVII		7	2	6	34 (2)	14	63 (2)	XVII	
Program in Science, Technology, and Society, XXI-T, STS		-	-	-	3	-	3	XXI-T, STS	
Total		22	20	36	91 (4)	14	183 (4)	Total	
SLOAN SCHOOL OF MANAGEMENT									
Management, XV		9	20	20	103 (5)	-	152 (5)	XV	
Management Fellows, XV-A		-	-	-	8 (2)	-	8 (2)	XV-A	
Management-Operations Research, XV-B		-	-	-	9	-	9	XV-B	
Management-Ph.D., XV-P		-	-	-	12	-	12	XV-P	
Total		9	20	20	132 (7)	-	181 (7)	Total	
SCHOOL OF SCIENCE									
Program in Applied Biological Sciences, XX		-	-	-	13	-	13	XX	
Biology, VII		42	56	30	68 (2)	-	196 (2)	VII	
Biology, VII-A		1	7	7	-	-	15	VII-A	
Biology, VII-B		-	-	2	-	-	2	VII-B	
Biology, VII-W (Woods Hole)		-	-	-	13	-	13	VII-W	
Chemistry, V		13	10	20	72	2	117	V	
Earth, Atmospheric, and Planetary Sciences, XII		2	5	11	19	1	38	XII	
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)		-	-	-	24	-	24	XII-W	
Mathematics, XVIII		5	16	18	16 (1)	2	57 (1)	XVIII	
Mathematics with Computer Science, XVIII-C		4	1	5	-	-	10	XVIII-C	
Physics, VIII		14	8	8	29 (1)	-	59 (1)	VIII	
Physics, VIII-A		2	1	4	-	-	7	VIII-A	
Total		83	104	105	254 (4)	5	551 (4)	Total	
WHITAKER COLLEGE of Health Sciences and Technology									
Brain and Cognitive Sciences, IX		6	4	8	10 (1)	-	28 (1)	IX	
Division of Toxicology, TOX		-	-	-	11	-	11	TOX	
Total		6	4	8	21 (1)	-	39 (1)	Total	
Harvard-MIT Division of Health Sciences and Technology, HST									
		-	-	-	15 (10)	-	15 (10)	HST	
Undesignated									
		30	10 (10)	-	-	-	40 (10)	Undesignated	
First Year									
		349					349	First Year	
Grand Total									
		349	347	368 (10)	396	1,024 (59)	35	2,519 (69)	Grand Total

¹All figures include special students (special students also shown separately in parentheses); not included are: 1 student in the third year, 2 students in the fourth year on Foreign Study; 3 students in the third year on Domestic Study

²Non-Resident graduate students
TOTAL UNDERGRADUATE WOMEN: 1,460

Office of Sponsored Programs

For fiscal year 1990, the total volume of sponsored research performed on campus approximated \$310,660. This represents an increase of 8.7 percent over fiscal 1989 volume of \$285,728 which was, in turn, an increase of 6.1 percent over the prior year.

Federal agency sponsorship increased by 8.7 percent, with Department of Energy funding up 13.1 percent, the Department of Health and Human Services up 10.2 percent, the Department of Defense up 6.8 percent, and the National Aeronautics and Space Administration up 21.0 percent. The National Science Foundation decreased by .02 percent.

Of the non-Federal sponsors, industrial funding increased by 10.2 percent, compared with an increase of 18.8 percent in 1989 and a decrease of 4 percent in 1988. Support from private foundations and other non-profit sponsors increased by 6.9 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 - 1984-1990 (in thousands of dollars)

<u>FEDERAL</u>		<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>
DOE	\$	51,489	56,363	54,511	55,062	55,629	54,045	61,098
DHHS	\$	36,324	40,252	45,735	47,310	49,070	52,565	57,915
DOD	\$	34,626	38,578	43,418	45,418	46,836	47,921	51,158
NSF	\$	30,876	33,658	36,772	38,091	39,177	38,962	38,093
NASA	\$	11,888	12,315	12,864	12,706	12,509	15,256	18,469
Other	\$	9,783	8,863	7,823	8,238	7,283	6,713	7,430
Federal Subtotal	\$	174,986	190,029	201,123	206,825	210,504	215,462	234,163
 <u>NON-FEDERAL</u>								
Industry	\$	27,686	33,456	36,290	36,601	35,315	41,937	46,223
Nonprofit	\$	15,743	15,282	15,532	15,319	19,779	23,602	25,220
Other	\$	33,166	2,958	3,151	4,009	3,796	4,727	5,053
Non-Federal Subtotal	\$	46,595	51,696	54,973	55,929	58,890	70,266	76,496
 <u>TOTAL</u>	 \$	 221,581	 241,725	 256,096	 262,754	 269,394	 285,728	 310,660

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:

Scientific Misconduct

New Public Health Service regulations, developed in response to increased Congressional concern over several cases of alleged scientific misconduct, became effective as of November 8, 1989.

Entitled "Responsibilities of Awardee and Applicant Institutions for Dealing with and Reporting Possible Misconduct in Science," the new regulations reflect an approach generally consistent with the existing MIT policy set forth in Policies and Procedures, which involves an inquiry to determine whether a detailed investigation is warranted, a thorough investigation of the facts, and a decision by the Provost as to disciplinary action. The existing MIT policy has been slightly modified to provide a generic statement which is consistent with the new PHS and other Federal regulations. A supplement to the generic MIT statement contains the specific PHS requirements applicable to research conducted with PHS funding and will accommodate any future agency specific requirements as they may be promulgated. The new MIT policy and supplement were distributed to MIT faculty in March of 1990.

Conflict of Interest

On September 15, 1989, the National Institutes of Health proposed new guidelines in its "NIH Guide for Grants and Contracts" which were intended to address potential conflicts of interest in research supported by NIH grants. The guidelines resulted in a largely negative response from a broad number of constituencies. In addition to the universities, comments were provided by the pharmaceutical and biotechnology industry, several state governments, and by Federal agencies including the National Science Foundation and the Department of Commerce.

On December 19, 1989, Department of Health and Human Services Secretary Louis W. Sullivan withdrew the proposed conflict of interest guidelines. He cited the widespread concern expressed as to their effect and noted that "While there is a crucial need to protect against possible abuses in the research system, it is also important that we not impose on our scientific community regulatory burdens which may be unnecessary or counterproductive." He indicated that the proposed guidelines would be reconsidered and reissued through formal regulatory procedures, i.e., as proposed rulemaking in the Federal Register, which provides a further opportunity for comment.

GAO Study of University Licensing Practices

In late spring, Representative Ted Weiss (D-NY) asked the General Accounting Office to survey the top university recipients of NSF and NIH research funding to look into their practices with regard to the licensing of research results. The central focus is on fairness and conflicts of interest rather than on the effectiveness of the technology transfer process. The major questions are: Which corporations have received either proprietary rights or exclusive licenses? How much stock do university executive officers and trustees have in these corporations, both foreign and domestic? What is the nature of industrial liaison arrangements entered into by universities and does it allow foreign nationals to get special advantages?

The GAO has identified 38 universities, including MIT, to participate in the survey and by year end had prepared a draft questionnaire which it intended to use in a pre-test or pilot survey with five of those institutions.

Lobbying

An appropriations act signed into law on October 23, 1989, incorporated an amendment by Sen. Byrd, entitled "Limitation on the use of appropriate funds to influence certain Federal contracting and financial transactions," to be implemented by all Federal agencies. Lobbying rules to implement the Byrd amendment have been effective on an interim basis since December 1989, but final rule making is not expected until late fall, although a number of clarifications have already been issued.

The rules are designed to prohibit recipients of Federal funds from using those funds to pay persons to influence or to attempt to influence executive or legislative decision-making on awards, whether in the form of contracts, grants or cooperative agreements, from any federal agency, provided the awards are above the statutory threshold of \$100,000.

Drug Free Workplace

On May 25, 1990, the Office of Management and Budget issued the final government-wide common rule implementing the 1988 Drug Free Workplace Act, which is directed at the use or possession of drugs at the workplace in connection with the performance of Federal grants and contracts. (As noted in last year's report, MIT has already issued its implementing policy guidance.)

The rule requires appropriate notification to employees that drug abuse is prohibited in the workplace, the establishment of a drug awareness program, notice by employees of criminal convictions for drug violations and imposition of sanctions or remedial actions for such employees. Drug testing is not required under the Drug Free Workplace Act (but is required, however, where the DOD drug free workforce regulation is applicable).

Costs of Research

We noted last year that the Association of American Universities had in the spring of 1989 distributed widely a paper (i.e., the "Pings report") making suggestions for simplifying and clarifying the rules that govern indirect cost reimbursement. The first active steps toward the implementation of the report were taken on November 7, 1989, when the AAU submitted the report to OMB Director Richard Darman. Subsequent meetings between OMB and university representatives took place in January and February and resulted in general agreement on substantive points and the decision to set up government and university working groups, which began detailed discussions during the spring.

On May 1, a group of university presidents and members of the working groups met with representatives of several scientific societies to identify points of agreement and disagreement and to clarify points of misunderstanding with regard to the Pings report. The discussion focused on the financing of research facilities and on charging directly the cost of specialized centers providing services to research. Other issues discussed included the use of separate indirect cost rates for support of research buildings, useful lives of research equipment and buildings, administrative cost thresholds, use of multi-year rates, permitting higher dollar thresholds for use of the simplified method of determining indirect cost rates, the charging of more costs directly, and greater uniformity in the costs included in the direct cost base.

We also noted last year that universities were attempting to remove various restrictions on the full reimbursement of Federally sponsored research. Despite these efforts, Congress imposed the same ceiling as in 1989 on the rate of compensation which could be charged to grants made from 1990 appropriations. In addition, it imposed a similar ceiling (although higher) on NIH grants made from 1990 appropriations, and approved limitations on indirect cost reimbursement under grant programs of at least one Federal agency.

Personnel Changes

Carol Van Aken, Associate Director, left OSP in May to accept a position in the Comptroller's Accounting Office, Barbara Greene resigned as Intellectual Property Coordinator in March to raise a family, and Barbara Bruno resigned as a Contract Administrator in January to accept a similar position at the University of Maryland. Marie Cedrone joined OSP in June as a Contract Administrator, and Lucille Piazza joined OSP in May as Assistant Contract Administrator.

GEORGE H. DUMMER

VICE PRESIDENT FOR INFORMATION SYSTEMS

The computer population at the Institute continues to grow and today numbers about 14,000 machines — some 11,000 personal computers; 3000 workstations; a few hundred time-shared minicomputers, minisupercomputers, and mainframes; and one supercomputer. As the number of machines grows, the importance of providing high data rate network interconnections between these machines increases. Also increasing is the demand for network-based services such as authentication and authorization; file storage; databases containing information such as the library card catalog, the full text of documents, the course catalog and class schedule, Institute job openings, and Institute policies and procedures; electronic directories; electronic mail; higher performance compute engines, etc.

The campus computer network (MITnet) was established in 1984, and today interconnects more than 3000 computers — from Macintoshes to the Cray 2 — in some 40 buildings on campus. It has become a fundamental part of the research and educational environment at MIT. In an effort to address the growing importance of the network and the need to provide more complete network services, Information Systems (IS) brought all of its networking activities together into a new department, Network Services, with Cecilia R. d'Oliveira as director, was formed in October 1989

Management of information technology at the Institute is broadly distributed. However, to maximize their effectiveness, these resources must interoperate. Departments must interact and cooperate in setting compatible directions and selecting effective technologies. Interaction and cooperation are also required to maximize the value of the Institute investment in information technology. During 1990 the Office of the Vice President for Information Systems worked in partnership with a number of Institute organizations to provide a foundation for the continued development of the Institute's information resources. These activities included:

- **Administrative Computing Principles for MIT**

In July, the Senior Vice President endorsed a set of Administrative Computing Principles which introduces practices to be consistently applied across central administrative organizations to plan, allocate, and monitor the use of information technology resources for administrative computing activities. These Principles also identify the functional directions that new Institute-wide administrative systems will take. The Steering Committee for Administrative Computing, composed of senior officers, was established to lead the implementation of the Principles.

The practices introduced in the Principles anticipate applying a standard methodology for developing all new information systems and for major work on existing systems. This methodology includes a uniform process for Steering Committee review of project proposals. This year the Steering Committee reviewed and approved a proposal for an electronic requisitioning system, the requirements analysis for a new student information system, and the requirements analysis for a new personnel records system.

- **Policy on the Use of Information Technology**

In December, the Academic Council approved a policy statement on the use of information technology. The statement, which is included in the 1990 edition of MIT's *Policies and Procedures*, covers privacy of Institute records; information security and preservation; responsible use of MIT computers, networks, and telephones; privacy of electronic communications; and the acquisition and use of third-party products and services.

- **Business Continuity Planning**

This year the business continuity planning effort, involving staff from across the Institute, accomplished major milestones. Central offices were surveyed to establish the criticality of their systems in the case of a disaster. Disaster recovery tests of the first two of the three most critical systems – Payroll, Admissions, and Registrar – were successfully completed, as was disaster recovery documentation for Payroll. The W91 Data Center continuity plan is now being drafted, and provisions are being made for alternate computing sites.

- **Collaboration with MIT Libraries**

This spring, senior staffs of MIT Libraries, Project Athena, and IS initiated a joint planning activity to give each organization a better understanding of the others' goals and plans and to identify and work on areas of mutual concern and interest. IS will encourage collaboration among the staffs of the organizations in delivering distributed access to library services at MIT, in working with potential vendors and sponsors to do so, and in participating in related regional and national initiatives.

One additional activity is reported here: progress on the implementation of the New England Academic and Research Network (NEARnet). NEARnet came into operation in February 1988 under the sponsorship of Boston University, Harvard University, and MIT. Today, it provides regional computer network services and access to the NSFnet to over 50 members — colleges, universities, research laboratories, and business firms — in Massachusetts, Maine, New Hampshire, Vermont, and, in the near future, Rhode Island. Initial funding for the network came from DARPA. Fees charged to members were designed for the network to be financially self-sufficient early in its operation; this goal was reached at the end of fiscal 1990. The NEARnet core is fully redundant and operates at 10 Mb/s, the highest data rate of the nation's regional networks. Additional redundant links are being installed to support other key network paths as finances permit. NEARnet's role in New England was recognized this spring when it was awarded one of three new NSFnet nodes. The node will be located at MIT and operate at 45 Mb/s.

Personnel

In September, Gary Panaro joined the Office of the Vice President as Assistant Director for Finance and Administration. Under Mr. Panaro's direction, IS financial administrators produce standardized budgeting and forecasting processes and reports. Special attention was provided to the group's larger financial activities, specifically the Microcomputer Center, Telecommunications Systems, and the central administrative computing budgets.

In October, Marilyn A. McMillan became Director of Information Systems Planning in the Office of the Vice President. Previously, she had been Director of Architecture and Strategic Technology. Penny Blaisdell was appointed director of Information Services; responsible for planning and directing the design, development, and delivery of end-user computing support services to the Institute's academic, administrative, and research communities.

The continued commitment of IS to affirmative action led to our creating a senior position and two entry level positions for promising minority candidates identified in our searches to fill open positions. Highly qualified women continued to successfully apply for positions in IS, with their total representation on the professional staff up slightly from last year.

ADMINISTRATIVE SYSTEMS DEVELOPMENT

One of Administrative Systems Development's most important project achievements this year was the completion of the ADDS Efficiency Project. This project, begun in 1989, sought to improve the performance efficiency and functional utility of the Alumni/Donor/Development/Schools (ADDS) computer system. The ADDS system, used by over 200 staff in the Treasurer's Office, Resource Development, Alumni Association, and school development offices, supports all of the *Campaign for the future* and annual giving programs. Through the joint efforts of ASD, other employees of IS, and the client staff, the ADDS Efficiency Project was completed ahead of schedule and under budget, and achieved the following goals:

- Extending the life of the system through the duration of the Campaign (and possibly beyond).
- Increasing the efficiency of the system (as measured by its use of mainframe computer resources).
- Making the system easier to use.
- Making the system simpler and less costly to maintain.

The success of the ADDS Efficiency Project led to the decision to initiate a similar project for the Freshman Admissions system. This project, begun in the spring of 1990, is a joint effort between ASD and the Admissions Office. It has similar objectives (making the Freshman Admissions system more efficient, easier to use, and less costly to maintain) and is structured similarly to the ADDS Efficiency Project. The first phase of this project will be completed at the end of the calendar year with the installation of the new on-line portion of the system.

Also, this year ASD implemented a service plan for performing preliminary analyses for administrative units around the Institute. ASD will provide up to four equivalent full-time personnel to conduct analyses of the business operations of these units. The goal of these analyses is to provide managers of administrative units and the Administrative Computing Steering Committee with the information to make informed business decisions regarding their own administrative applications. Analyses are one way ASD ensures the delivery of quality application systems that meet administrative needs.

Other key project accomplishments included:

- Offering customized application development and support services to users of Macintosh computers. Using 4th Dimension, a powerful relational database management system for the Macintosh, ASD assisted three offices (Microcomputer Center, Alumni Association, and the Center for Materials Science and Engineering) in the development of new or maintenance of existing applications to meet their business needs. ASD expects additional projects of this type in the future, and will be investigating offering similar application development services to IBM PC and PS/2 users.
- Assisting the continuity planning and disaster recovery efforts of two of its clients, the Payroll Office and the Admissions Office. As joint efforts between ASD, Operations and Systems, the Information Security office, and clients, these projects develop and test plans for the running of the applications on alternative computers should a disaster strike the IBM 3090 mainframe in Building W91. Similar projects for other major administrative applications around the Institute will continue in the future.

- Distributing the ASD *Quality Assurance Standards Manual* to managers in twelve different departments around the Institute, as well as to ten other universities in the United States and Canada. Efforts began and will continue into 1991 on enhancing the *Manual* and expanding the scope of the areas it covers. The *Manual* also received a merit award in a competition sponsored by the Society for Technical Communications.
- Performing a preliminary analysis for the Microcomputer Center to assist in selecting a new point-of-sale and inventory management system. This analysis resulted in the Microcomputer Center's selection of a cost-effective packaged solution that avoided the need for development of a customized computer solution.
- Installing the new Children's Scholarship Plan system. This system, integrated with the Institute's Personnel System, supports the Benefits Office in its operation of the Children's Scholarship Plan for employees.
- Installing the Service Order system for Telecommunications Systems, which allows the customer service representatives and other employees to process on-line orders for new and changed telephone service throughout the Institute. ASD also assisted Telecommunications Systems with its effort to clean up its billing database and to recover back telephone charges from MIT departments, laboratories, and centers.

ASD continued to increase the skill levels of its staff through education, training, and representing MIT at professional conferences. Over 400 person-days of skills training (an average of ten days per employee) were delivered to ASD staff in 1990, and 150 person-days were spent at professional conferences. Activities with professional organizations included presentations at national conferences by a number of ASD staff, as well as publishing articles and helping in the organization of the conferences. ASD also sponsored an additional 85 person-days of training for client staff as well as others in IS.

A new administration will begin to take shape at the Institute. That event, along with changes in technology, will continue to necessitate adjustments to the services that ASD provides. Steps taken this year build on previous years and have helped to ready ASD for these changes.

DONALD E. HELLER

INFORMATION SERVICES

The mission of Information Services has been redefined over the past year to support the direct delivery of end-user computing support services to the Institute, including the sale of computing equipment and services, training, consulting, publications, and software acquisition. Objectives are:

- To maximize the self sufficiency of individuals, work groups, and departments so they can make informed acquisition decisions about information technology and can use that technology effectively.

- To create and promote convenient access to computer products and services at reduced cost through economies of scale and centralization.

Clients of Information Services include the entire Institute: faculty, students, and staff. This past year we have focused our efforts on recovering the majority of our costs, developing a concise strategy for decentralized computing in a multi-vendor environment, encouraging productive vendor alliances, delivering quality and timely customer services, and promoting a nurturing and productive work environment to foster an enthusiastic staff.

In September 1989, as an outgrowth of the Network Services department, a new microcomputer consulting, troubleshooting, and referral team, called **Microcomputing Resources (MCR)**, was formed. This group consists of five full-time staff members plus several student employees, all of whom answer technical questions and resolve computing problems. The group:

- Provides direct support to callers to the Information Services Help Line (253-0001).
- Strengthens collaboration with computer user groups meeting on the MIT campus. There are now over two dozen such group meetings each month. One of these user groups, called Tech Partners, provides a special link between Information Services and the computer experts who support their individual organizations. The MCR provides special access to technical information and training to these user groups; in turn, they extend the reach of MCR technical resources by helping end users locally.
- Provides data recovery from damaged disks and detection/eradication of viruses and other malicious programs.
- Tracks and assists with new or newly-popular technologies for which there is interest on campus, for example, CD-ROM storage, optical character recognition systems, electronic publishing, and dial-up access to computers via digital phones. Continued MCR collaboration with the Microcomputer Center ensures the Center's offering of appropriate and current technologies to the Institute.

Information Services continues to expand the range of products and services it delivers to the Institute community through the following programs:

The **Microcomputer Center (MCC)** is now in its sixth year of operation. Currently, Apple, IBM, and NeXT products are sold and serviced. In 1991, the MCC is planning to add DEC workstations to the MCC product line and is reviewing the feasibility of adding SUN workstations and the IBM RS6000 product lines. Sales for fiscal 1990 were \$9.2 million, down from \$10 million in 1989. Expenses were reduced in 1990 to compensate for the decrease in revenue, which resulted from decreased vendor prices and a flattening of Institute and student microcomputer purchases. The MCC inventory was substantially reduced in 1990 from \$3.3 million to \$1.2 million.

The MCC is establishing innovative service programs to address the shifts in the Institute market. The personal computer rental program, which was initiated early in January with Macintosh rentals, has been well received and is being expanded to include IBM products. Also, in 1991, the MCC plans to introduce a trade-in program and offer additional repair and maintenance options. The **VAX Resource Center (VRC)**, in its third year of operation, provides DEC maintenance services at a discount for some 280 DEC CPUs on campus. This represents the majority of non-Athena DEC systems at the Institute. Software licenses and update services are also offered at a discount for about 150 DEC CPUs. Centralized software acquisition services are provided through Vendor Services. Software purchased on behalf of the Institute clients included math, statistical, graphic microcomputer software, and several other mathematical packages and language compilers for larger systems. In addition, the software update service for SUN Microsystem workstations grew 50 percent in its second year of operation to 150 CPUs. I

In 1991, SUN workstation users will be able to purchase discounted SUN maintenance service at a substantially lower cost.

Training Services provided a variety of computer training opportunities to the MIT community. Over 1200 people attended hands-on training sessions in the Microcomputer Training Lab. These courses included Quick Start classes and Getting Started courses for new computer users, software application courses, and Business Modules designed to teach staff how to accomplish specific MIT administrative tasks on their computers. In addition, Training Services also sponsors a noontime seminar series on computer related topics and Graduate Thesis workshops throughout the spring semester.

Publication Services provided significant documentation support for two newly developed Network Services products — TechMail and TechInfo —that are available on MITnet. In addition, they introduced usability testing to ensure ease-of-use of their products. Major new publications in 1990 include the *User's Guide to the MIT Voice Mail System* and the *Catalog of Computer Hardware and Software*.

Publication Services also produced ten issues of *i/s*, MIT's newsletter on information systems, promotional material to market IS services, Quick Reference Guides, and reprints from computer publications to help users become more knowledgeable about their systems and the Institute's computing facilities.

To make documentation more accessible and to provide greater visibility for IS, four new distribution points were set up in Building E19, the Sloan School, IS user accounts, and the training lab.

PENNY BLAISDELL

NETWORK SERVICES

Network Services was established on October 1, 1989, to operate MITnet, the campus computer network, and to coordinate services from IS to network users. Staff from Administrative Systems Development, Architecture and Strategic Technology, Information Services, Telecommunications Systems, and the Office of the Vice President were brought together to form the new organization.

Growth of the MIT campus network continued at a fast pace during the fiscal year as the number of computers on MITnet grew by 20 percent to approximately 3500 across 23 individual connected networks. The network now carries, on average, over 4600 electronic mail messages per day. MIT ranks among the top five users of the NSFnet, the national research network. Project Athena continues to be the primary client of MITnet with over 1000 workstations that rely on the network for printing, on-line consulting, file service, electronic mail, authentication, and service management functions.

During the year Network Services pursued several initiatives designed to increase the reliability and performance of the network. Plans were drafted for a major upgrade of the campus network spine with installation of commercial FDDI routers. This project is scheduled to begin during the summer of 1990 and be completed during the next 18 months. Initial versions of network management software were

developed and installed to permit monitoring the network from staff offices and to quickly detect developing network problems. Developing approaches to help manage a growing network environment in a cost-effective manner will continue to be one of the highest priorities in the coming years.

Many faculty, students, and staff still lack MITnet connections in their offices, laboratories, dormitory rooms, or homes. Some of our activities this year were designed to address this increasing issue of access to the network. In conjunction with Telecommunications Systems, we introduced a service that provides dial-up access via the campus telephone system to Project Athena computers, Purchasing Department's new electronic requisitioning system, and selected other computers on MITnet.

In the past, design of network connections has been a time-consuming task that delayed service delivery. The goal of the unshielded twisted pair (UTP) Ethernet project is to standardize the network connections to provide timely network connectivity at a standard price. This year we evaluated equipment from several vendors and outlined a phased approach for implementation. Necessary infrastructure work was completed within several buildings targeted for the first phase; preliminary pricing scenarios, financial models, and administrative procedures were developed. Introduction of the service, which awaits completion of product evaluation and vendor negotiations, is anticipated early in fiscal 1991. Service will be expanded to encompass the entire campus over the next several years.

During the past year the range of support services offered to network users was expanded:

- A Network Help Desk was established to provide a single point of contact for all network-related problems, questions, and service requests.
- New documents were developed for network users including: *Addressing Electronic Mail, Avoiding Problems With Your MITnet Connection, TechMail Getting Started Guide for Macintosh Computers, Connection Alternatives for Macintosh Computers (revised), A Quick Guide for TechInfo on MITnet for Macintosh Users, and Dial Up Access to MIT Computers and On-Line Services*
- Network-related seminars were offered during the year on topics including electronic mail, supercomputing, MITnet overview, TechMail, departmental networking options, overview of the Internet, and authentication (Kerberos.)
- Users were assisted in migrating their work from JvNC to other supercomputing sites in conjunction with the closing of the JvNC.
- MITnet connectivity kits were introduced at the Microcomputer Center for Macintosh and DOS users.

Looking to the future, we see increased need for network-based services such as authentication and authorization, security, electronic mail, electronic directories, and access to various types of information. During the past year, activities which address these future needs included the introduction of:

- The on-line staff and student directory, now updated on a monthly basis with information provided by the Personnel and the Registrar's offices. Since its introduction, the service has averaged over 1000 electronic requests per day.

- TechMail, a network-based electronic mail facility for Macintosh users, which is now used by over 200 individuals. A follow-on project is underway to extend TechMail to Macintoshes connected to the campus computer network via digital ISDN phones; this software is scheduled for release in summer 1990.
- TechInfo, a network-based public information service. The information currently available includes policies and procedures; course catalog and class schedules; Lab Supplies catalog; articles, classified ads, and job postings from *Tech Talk*; National Weather Service forecasts; and various IS publications. The information is geographically dispersed, residing on many different computers on the network, although this is transparent to the user. Software was developed to allow easy access to the information by Macintosh users on MITnet. Work continues on software that will allow MIT offices to easily input and maintain the information they supply to the service.

The Network Services staff continues to participate in professional, special interest organizations, such as the Internet Engineering Task Force, that work toward the establishment of national and international networking standards.

CECILIA R. d'OLIVEIRA

OPERATIONS AND SYSTEMS

During fiscal 1990, Operations and Systems concentrated on improving the quality of its services while reducing costs. With the establishment of Network Services last fall, the responsibility for mainframe computer consulting was transferred to Operations and Systems. To accommodate this new responsibility and to expand the availability of services to clients, we established the Client Services group to act as an interface for all services provided by Operations and Systems to its clients. Client Services incorporates the functions previously performed by Production Services.

Client Services also serves as a contact for new service offerings. One example is the laser forms service, established to aid clients in the conversion of preprinted, line-printer forms to electronically created forms that can be produced and printed on our high-speed laser printers.

By September 1989, the Cray 2 supercomputer was up and running. This system, housed in Building W91, is operated by Operations and Systems on behalf of the MIT Supercomputer Facility. The utilization of this computer has grown from an initial ten percent to roughly 40 percent. The Cray has been very reliable; providing approximately 96.7 percent up time (not including the scheduled periods of 17 hours a month for normal maintenance).

The new IBM 3090-150S computer, installed during the last half of fiscal 1989, has proven extremely cost effective and reliable. This computer has doubled the computing capacity available to central administrative computing clients. It has provided 98.9 percent overall up time and 99.7 percent up time during the prime hours of 9 AM to 6 PM. The average number of users on the two IBM computers during prime time increased by approximate a ten percent increase over fiscal 1989.

A number of equipment upgrades occurred during this year. The Xerox 8700 laser printer in Building 11 was replaced with a new Xerox 4550 printer to improve reliability and to provide access to new features that will benefit clients doing specialized printing. A new IBM 3820 printer was installed in Building E19 to provide faster access to reports generated by clients in that area.

Operations and Systems has also initiated contingency planning to provide for the continuation of the Institute's critical data processing services should the Building W91 facility be disabled. This is a cooperative effort between the Office of the Vice President, Administrative Systems Development, and client departments in the areas affected. ComDisco's COMROC division has been identified as a provider of a portable machine room shell in the event that Building W91 is unusable. Included in the plan is the mechanism to obtain replacement computers, software, and related equipment along with the procedures to restore applications on the new equipment. The basic plan will be completed in early fiscal 1991; a schedule of regular tests will be established to insure the plan remains feasible and current.

ROGER A. ROACH

TELECOMMUNICATIONS SYSTEMS

Telecommunications Systems is responsible for providing voice and data communications services throughout the MIT campus. The MIT 5ESS switching system, a state-of-the-art system, supports connectivity for both Integrated Services Digital Network (ISDN) interfaces and conventional analog and digital technologies. Currently, there are approximately 4800 digital telephones in operation, making MIT's 5ESS one of the largest ISDN systems in the country.

In addition to supporting analog and digital telephones, Telecommunications Systems uses ISDN to address a number of applications, as described in the examples below.

- MIT's Octel Aspen Maxum voice mail system is connected to the 5ESS by means of an ISDN interface, allowing for full interconnection and integration of the voice mail and telephone systems. Of the 3650 voice mailboxes currently in use, 2500 are basic voice mailboxes and 1150 are Enhanced Call Processing (ECP) services offering special services.

BENtalk, the Benefits Office's automated telephone system for obtaining general information and requesting forms and benefit materials, uses some 350 ECP mailboxes. BENtalk is an example of an "Information Tree", a special voice mail application an office can use to develop their own voice mail application. Such an application directs callers to other MIT telephone or voice mailbox numbers, to numbers for more information, to menu selections, or a combination of these.

The remaining 800 ECP voice mailboxes offer a combination of ECP services such as "Information-Only Mailboxes", in which callers hear only more recorded messages without being able to select further options; "Information-Reply Mailboxes", in which callers hear one or more recorded messages, which they can replay, reply to, or continue to the next message; and "Transfer Mailboxes", which enables incoming calls to be routed immediately to a predetermined destination, either another telephone or a mailbox number.

- The Purchasing Department's electronic requisitioning system and Project Athena's dial-up services use multi-line hunt groups to transport B channel packet data (at data rates up to 64 Kb/s) through protocol translators (translating the X.25 protocol of the ISDN switch to the TCP/IP protocol of MITnet). These services are not restricted to ISDN digital telephones. For example, by using the 5ESS modem pool, analog telephone users either on- or off-campus can originate Telnet sessions on hosts connected to MITnet at data rates up to 2.4 Kb/s. Work on these services was a team effort between Telecommunications Systems and Network Services.

During the past year, changes were made in the MIT switched network. AT&T replaced MCI as the carrier of choice on calls placed from MIT by on-campus residents via the 5ESS, and AT&T and New England Telephone introduced new bulk-rate services as a means of reducing or stabilizing long-distance calling expenses.

To provide faster and more efficient service to MIT departments, Telecommunications Systems implemented a number of organizational changes during the past year. A specific Customer Service Representative is teamed with a Customer Billing Representative and a Transmission Facilities Analyst to service all departmental voice and data communication needs including orders for new or changed telephone service, problems with telephone service or bad phones, billing questions and adjustments, and non-network data communication connections.

In conjunction with Network Services, MITnet was physically extended to eight additional campus buildings — buildings 8, 12, 18, 41, 44, N10, N51, and N52 — this past year. In addition, the MIT Cable Television network was extended to all buildings north of Vassar Street.

At the end of the fiscal 1990, new telephone rates were implemented. Initial rates for telephone service provided by the 5ESS system were announced in September 1987, some thirteen months prior to placing the system into service. These rates were based on estimates of project expenses, operating costs, and operating income. However, final project expenses were greater and operating income less than expected, necessitating rate increases. Following an extended review of the rates and the appropriate approach to adjusting them, and an assessment of the impact of rate increases on the budgets of every MIT department, senior MIT management elected to increase rates effective July 1, 1990, by approximately 20 percent.

MORTON BERLAN

SENIOR VICE PRESIDENT

Major design and construction activities this year included the substantial completion and occupancy of the new graduate student apartment complex at 143 Albany Street. The 190-bed facility offers apartment-style living in efficiency, one, two, three, and four-bedroom apartments and duplexes. Design progressed on the new Biology Building to be situated on Ames Street adjacent to the Landau Building. Construction of the proposed six-story facility is scheduled to begin early in 1991 with completion expected in mid to late 1993. The addition to Building 7 to house the Rotch Library Collection was substantially completed this year and renovation work in the existing library will proceed over the summer.

Phase I of the conservation rebate program was completed during the year. The program has proved very effective and, at current prices, the Institute should realize an annual savings of over \$1.5 million and the rebate due from Cambridge Electric Light Company will be \$1 million per year for a five-year period. The success of Phase I has generated a new, more permanent program, Phase II, which is just beginning.

With the importance of environmental issues in mind, MIT has initiated a paper recycling program to recover all white ledger and computer paper from the Institute's waste stream. A pilot program was implemented in several East Campus buildings this spring. The response was so positive that the program is now being expanded throughout the Institute.

After many years of failed attempts, the Institute was successful in purchasing an appropriate piece of property for the purpose of housing Alpha Phi Sorority. The purchase of the property, located at 477-479 Commonwealth Avenue in Boston, was made conditional on Alpha Phi's securing zoning and licensing approval for the use of the buildings as a sorority house. After a long and complex process, the necessary permits were obtained. The planning and design process for the renovation of the sorority house was initiated with the expectation that members of Alpha Phi will occupy the house in the summer of 1991.

Affirmative Action efforts continued this year. Increasing the numbers of minorities and women in administrative staff positions continues to be our top priority. During the year, of the 12 staff openings filled, one was filled by an under-represented minority and 7 by women. While these results represent substantial progress in attracting women, the same cannot be said relative to the recruitment of minorities. However, we are committed to continuing aggressive action on this front.

Following are individual department reports.

WILLIAM R. DICKSON

Campus Activities Complex

This year, the Campus Activities Complex (CAC) placed major emphasis on improving the management of both its environment and the programs conducted within its area of supervision and responsibility. Modifications to event scheduling and space management, safety requirements and procedures, financial controls, and the general condition of facilities resulted from these efforts. In an effort to maintain staff effectiveness in light of growing demands, a student employment program was developed to offer jobs to students in specially identified areas.

Coordination of campus events remained a major function of the CAC. The department provided program planning and support to over 6,000 events within the Complex involving over 300,000 people. Major events included the Massachusetts Governor's Economic Summit Meeting; the President's Ball; and the traditional events of Residence/Orientation, Spring Weekend, Commencement, and Technology Day.

Efforts to support student and community programs were expanded this year. The Information Desk was opened in the Stratton Student Center serving the West Campus in a joint operation with the Student Center Committee (SCC). Plans are being explored to establish a campus-wide box office operation. In addition, efforts are underway to integrate event information with the campus network. The Stratton Student Center Vendor Program, encompassing daily table rentals by entrepreneurs selling a variety of goods and services to the community, generated over \$20,000 of new income, offsetting the operational costs of the Information Desk.

The department also expanded its management and supervision of Walker Memorial. Daily facility tours were implemented by the operations staff; increased coordination and supervision of the Walker gymnasium and recreation areas were implemented; and facility and safety reviews were conducted in conjunction with Physical Plant, the Safety Office, and Campus Police.

The department moved closer to the completion of renovations on the fifth floor of the Student Center. These renovations will provide improved office space for CAC and MIT Food Services as well as new study facilities and improved lobby areas.

A client team reviewed Kresge Auditorium and the Chapel and made recommendations to improve handicapped accessibility. The department also worked with Physical Plant to identify other maintenance needs for these facilities

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 assist the community by providing 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 1,759 complaints (situations which required the recording of an incident by a police report) recorded this year, a 13 percent increase over last year. Of these complaints, 22 were in the crimes against person category. Campus Police officers made 89 arrests on MIT property this year.

Larceny continued to be the largest category of crime with which the Institute had to contend again this year. Although the total number of reported incidents of larceny was 143, the total dollar loss was down 53 percent over last year for a total of \$169,274. Computers and computer components were, once again, the most frequently stolen type of Institute-owned property.

Personal property (non-residence) thefts were up 48 percent with 277 incidents totaling losses of \$52,105. Wallets and purses again led the list of items stolen.

The number of residence hall losses was up with a total dollar loss of \$19,027.

Motor vehicle thefts increased this year for a total of 41 vehicles stolen.

Emergency medical services decreased 14 percent this year for a total of 1,776 runs (including emergencies, transfers, and medical shuttles).

The Campus Police provided 5,615 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

The number one priority at Endicott House continues to be focused toward attracting residential business. Due to a drop in demand from non-profit businesses, this year's marketing campaign has been directed towards increasing corporate business within permissible guidelines. Another marketing strategy involved offering MIT departments, via a mail campaign, the opportunity to combine a day-long work session with recreational activities. This effort was made to better utilize the house over the summer months as well as in response to day groups requesting the use of recreational facilities normally reserved for residential groups. Several departments that have taken advantage of this offer have been very pleased.

Funding for capital improvements continues to present a challenge. Improvements made this year include waterproofing sections of the main building, redecorating eight bedrooms and associated bathrooms in the Brooks Center, and staining an exterior section of the Brooks Center. Considerable effort was spent on the main house mechanical system which will require major work in the future with the replacement of steam distribution lines and associated system components. A study is underway to scope the project for a phased approach. A major problem also occurred this winter with the failure of the greenhouse heating system due to rusted steam heating supply lines. Appropriate repairs were made on a temporary basis with the intent of replacing the original antiquated system this summer.

On a hopeful note, the Institute is currently exploring the possibility of selling a five-acre plot of land given to MIT by former Board Member and neighbor, Russell Stearns. The proceeds of this sale would be utilized to establish an endowment fund for capital improvements at Endicott House. As a noncontiguous parcel of land, it has no value in terms of the Endicott House operation. With prior approval by the Board of Governors, informal discussions have been held with neighbors informing them of these developments. Discussions concerning this proposal will continue.

In regard to the Stearns' estate and the eventual transfer of the property to MIT, no further action has been initiated by their legal counsel. The house continues to store original belongings and the grounds are maintained by Stearns' personnel.

Once again, the participants of the Fall and Spring Senior Executive Programs have rated the food, housekeeping, and overall ambiance at Endicott House a first-class operation.

From a statistical standpoint, Endicott House continues to be fairly well used by both MIT and non-MIT groups. Throughout the year, Endicott House and the adjoining Brooks Center were used 283 days and 165 nights by 211 groups. This compares with 301 days, 187 nights, and 237 groups last year. Of these groups, 94 were affiliated with the Institute and 117 were non-MIT groups. There were 33 conferences that required overnight accommodations ranging in duration from one night to the School of Management's nine-week Senior Executive Program. Of the residential groups, 22 were from MIT and 11 were not. There were 6,718 room nights used and 25,853 meals served during the year.

HOWARD F. MILLER

Graphic Arts and Audio Visual Services

Total income for all Graphic Arts Services was \$6.3 million, an increase of 5 percent over last year. The income generated by the Copy Centers increased 25 percent while the combined income of the Photographic, Illustration, and Typesetting departments was down 15 percent.

Conversion of the Offset department data base from an obsolete mini-computer system to a Macintosh network of computers and peripherals was completed during the year. This new system is presently being used in the Offset Printing and Mailing departments to assist in order entry, estimating, inventory control, and cost accounting and its use is expected to be incorporated throughout Graphic Arts in the near future.

Two major items of equipment were purchased this year. A Heidelberg two-color perfecting press which is due next year and an Omega saddle binder for the Offset Printing Department. This binder will enable the department to do in-house finishing/binding jobs which previously had to be done by an outside vendor.

JAMES W. COLEMAN

Housing and Food Services

One of the major accomplishments this year was the completion and occupancy of the new graduate apartment complex at 143 Albany Street. This facility offers apartment-style living for 190 graduate students in efficiency, one, two, three, and four-bedroom apartments and duplexes. All units are unfurnished and have carpeting, central air-conditioning, and fully aplianced kitchens. All units except for efficiencies offer a separate living/dining area. Common areas include a laundry room, a 150-capacity reception room with a kitchen, and a smaller room for study or private use. Between the buildings is a large, secure grass courtyard for the residents' social use. There are four units available for handicapped students and the building is accessible for handicapped visitors.

Another accomplishment this year was the implementation of the Plan to House New Graduate Students. This Plan responds to graduate student majority opinion that first-year students should be given priority for on-campus housing. Implementation of the plan will make available, over the next three to five years, enough on-campus beds for those first-year graduate students who wish to live on campus. This goal will be achieved by converting a renovated Tang Hall to a first-year graduate residence and achieving a 50-50 distribution of first year and continuing students at Green Hall, 143 Albany Street, Eastgate, and Westgate and approximately a 40-60 split at Ashdown House. The process uses a two-tier lottery system, one lottery for incoming students and another for continuing students. Tang Hall is currently undergoing renovation and furnishing to serve its new graduate housing mission.

Food Service highlights involved the development of stronger student communication programs. These programs included biannual satisfaction surveys, meetings with House and Undergraduate Association food services committees, and weekly comment tables regularly staffed by Food Services personnel. As a result of these outreach efforts, service issues and program enhancements included SAVE, an environmental program developed with a student organization to reduce the use of disposables and minimize our impact on the environment, and TREAT YOURSELF RIGHT, a nutrition identification program which encourages students to make informed and healthy dining selections.

Renovations that expanded the catering and conference capabilities of the MIT Faculty Club were completed as was the new computerized reservation system to maximize Club space and service use. A new Club credit card system was developed and implemented with assistance from the Accounting Office.

LAWRENCE E. MAGUIRE

Office of Facilities Management Systems

During the year, the Office of Facilities Management Systems (OFMS) continued to strengthen its major functions. The office's primary purpose is the operation and maintenance of the MIT/OFMS-developed space accounting system, INSITE, for the Institute's 9.16 million gross square feet of space in owned and leased academic buildings. This includes such ancillary services as field audits, room number assignments, indirect cost and other special reports, historical record keeping, and floor plan maintenance.

This year marked the completion of an intensive two-year digitizing effort that has resulted in converting MIT's 757 floor plans into intelligent electronic images that were then electronically stretched to their individual construction dimensions. The resulting room, floor, and building areas were then matched with their earlier manually calculated counterparts to provide a much more accurate Institute-wide facilities database that can be updated more easily than in the past. In addition, ten MIT departments are now utilizing these electronic floorplans via CADVIEW, an OFMS-developed, read-only graphic system that runs on a personal computer.

In the past year, the INSITE Consortium added three new sites where INSITE is used. The Consortium members reimburse the department for the training, application guidance, and systems support they receive, while the Institute realizes the benefits of informational exchanges and funding to pay for all of the OFMS INSITE systems support activities.

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. This year also marked the second year of an intensive summer program in FM for the Japanese Facilities Management Association (JFMA). Funded by the JFMA, the course is jointly presented by OFMS and the School of Architecture and Planning.

KREON L. CYROS

Physical Plant Department

Facilities Construction and Renovation

The Graduate Student Housing Facility at 143 Albany Street was substantially completed this year and students began moving into the 87 apartment-style dormitory units. Full occupancy is anticipated by the beginning of the next academic year. The addition to Building 7 to house the Rotch Library collection was also substantially completed by year end and renovation work in the existing library will proceed over the summer. Completion of the entire facility is scheduled for this fall.

Design continued during the year on the new Biology Building to be sited on Ames Street adjacent to the Landau Building. Current plans call for a 208,000 gross square foot facility, with six stories above grade and one basement. Tunnel and bridge connections to the Landau Building and a tunnel across Ames Street to the Seeley G. Mudd Building are also planned. Construction is scheduled to begin early in 1991 with completion expected in mid to late 1993.

New projects initiated during the year include renovations to the President's House and the former A.D. Little Building (E56) at 38 Memorial Drive and demolition of Building 58. The President's House project consists of modernization of the heating system and addition of air conditioning; improvement of handicapped access including installation of an elevator; installation of a new dumbwaiter; and upgrading of fire safety, sprinkler, and electrical systems. The former A.D. Little Building was transferred to academic plant and minor improvements were made to enable partial occupancy by the School of Management. Extensive renovations to further accommodate the School of Management and other activities are scheduled for fiscal 1991. Building 58 was emptied of large amounts of obsolete equipment and it will be demolished over the summer to clear a new building site in accordance with the Northeast Sector Development Plan.

Several major renovation projects were active during the year. The ice rink surface in the Johnson Athletic Center was replaced last fall with the conversion of the freon coolant system to a brine system. Design started on a project to convert Lecture Hall 2-390 into three levels of offices for the Mathematics Department which will accommodate both faculty and graduate students. Extensive renovations are continuing in Buildings N51 and N52 on Massachusetts Avenue to house the expanded undergraduate program for the Arts. Space was renovated on the fifth floor of the Stratton Center to house Campus Activities Complex Offices and portions of Dining Services, the Dean for Student Affairs Office, and Project Athena. Renovations for a new language learning laboratory and other Humanities-related activities were completed on the middle floor of Building 20C.

Management Information Systems

Development of the new Physical Plant management information system has progressed, with more users and improved functionality. Grounds personnel can now access a campus-wide landscape database to assist them in the planning for and care of trees, shrubs, and flowers. A new Preventive Maintenance (PM) program is currently being tested by the PM Office. Plant personnel have access to an expanded on-line equipment database. A new labor module, which will track labor costs and integrate with the Institute's Payroll system, is still under development and is scheduled to be completed this summer. Work has begun on a new inventory module which will improve management of Plant's stockroom and afford better inventory control.

Energy Consumption and Prices

Fiscal 1990 was a good year for energy consumption at the Institute and a disappointing year for energy prices. Despite a heating season which started with the coldest December in history, our year-end consumption results for heating fuel and electricity were better than in recent years and better than we had forecast. However, the price of fuel oil was up by over 30 percent - to the highest levels since 1986 - during the December cold snap which reflects the continuing volatility and instability in the energy pricing mechanisms in New England. Recovery from the price increase was typically much slower than the price rise, carrying over until early summer. In the New England electric industry, still tied to an imported fuel oil generation base, the fuel price rise was immediately reflected in the electric fuel adjustment, resulting in a steep increase in electric costs. Overall, our electric costs increased by more than 20 percent over last year.

Electric Energy Conservation and Rebate Program

Phase I of the conservation rebate program is essentially complete. This program has been a very effective load control strategy for the Cambridge Electric Light Company and was their "trial balloon" with an intentionally short implementation period. At current prices, we will realize an annual savings of over \$1.5 million and the rebate due will be \$1 million per year for a five-year period. MIT's obligation to the Energy Service Companies is \$5.8 million plus financing costs. The success of this program has generated a new, more permanent program, Phase II, which is now beginning. The rebate incentives offered in the new program are even more exciting than the original program to the extent that we expect to pick up conservation options which were less than marginal under Phase I.

Main Group Air Conditioning Program

In 1980/81, MIT set in motion a long-range plan to upgrade the original office, classroom, and laboratory spaces in the main group to be more comparable to the new, fully air conditioned facilities built more recently. After nearly a decade of activity, the success of that program can be measured by the results of a recently completed space survey of the main group. The survey disclosed that the original main group buildings are now 55 percent air conditioned. That number represents roughly twice the space air conditioned when the program began in 1980. The program will continue until all viable space is brought to an acceptable standard.

Cogeneration Project

Cogeneration activity for the year focused on an intense effort to obtain air permits. The Massachusetts Department of Environmental Protection's (DEP) recent adoption of an area-wide recommendation for emissions limits on NOx, generally forces the application of Selective Catalytic Reduction (SCR) on gas turbine exhausts. Because we propose to generate both steam and electricity in accordance with our actual hourly requirements, the use of SCR comes into question and thus we have based our licensing strategy on the utilization of other technologies. We expect resolution of this issue early next year.

Building Maintenance

In addition to the ongoing daily maintenance, completion of a facility upgrade for student activities in Walker Memorial was completed last year. The Carpenter Shop, utilizing a design by the Design and Construction group, restored the 73-year old Memorial Drive entrance to Walker Memorial by fabricating and installing new doors. The exterior of the Dreyfus Building was re-caulked and new floor tiles were installed in all of the perimeter corridors. The Pierce Boathouse has received a new roof and exterior paint. Major projects now underway are the painting of the Calder Sculpture in McDermott Court and the repair of the pile substructure which supports the

Walter C. Wood Sailing Pavilion. Roofing is a continuing problem as many roofs have outlived their normal serviceable life. As a result, the lower roofs of the Compton Laboratories and the roof of the Plasma Fusion Center are scheduled for replacement. The East, West, and Albany Street Garages have once again been inspected and plans and specifications for repairs to the decks are being developed.

Paper Recycling Program

The department has initiated a paper recycling program to recover all white ledger and computer paper from the Institute's waste stream. The major objectives of this program are the conservation of our natural resources with the attendant reduction of material going to landfills and the associated reduction in tipping fees. A pilot program was implemented in several East Campus buildings this spring. The response was very positive and the program is now being expanded throughout the Institute.

Building Services and Grounds

Over the past year, efforts have been concentrated on shrub and lawn replacement, with special attention being given to the replacement of high maintenance lawn areas with ground cover plantings. A feasibility study for utilizing water from the Charles River to feed the Killian Court and Briggs Field irrigation systems is being investigated.

HARMON E. BRAMMER

Planning Office

The Planning Office's efforts in FY90 were designed to prepare for the new decade ahead, and for the change in administration presently underway. Our research, analysis, and planning efforts have addressed each of these key resource areas in specific ways.

Capital Planning: An extensive inventory of the potential capital projects, their projected costs, and their location on the campus is nearing completion. It provides a comprehensive picture of those needs and their implications for land and financial resources for the next 10 to 15 years.

Land Use and Development Planning: A major study of the west campus Vassar Street area is in its final stages. Primarily focussed 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. Related planning for graduate student, faculty, and staff housing is also underway. In addition, a land resource requirements analysis was prepared for the Corporation's Real Estate Sub Committee.

Transportation Planning: 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 explores 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.

Landscape Planning: 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 Department of Physical Plant as a reference for maintaining and enhancing the MIT environment. The graphical record of these data is being updated to a mapping reference system keyed to the campus base maps maintained by the Planning Office.

Facilities Planning: A report on the renovation of Building 16, relocation of its current occupants into spaces in Building 56 (to be vacated by the Biology Department), and relocation of certain Physics Department activities into a renovated Building 16 was completed and presented to the Committee for Review of Space Planning. The report on animal care facilities completed last year has been an integral element in planning for the new Biology facility to be located on Ames Street along the edge of the main campus. Planning for a new science teaching center is under discussion, and the renovation and refurbishment of existing classrooms enters the second year of a 10-year implementation plan. The development of a program to meet the Sloan School's needs for classrooms and lecture halls has begun, and the Rotch Library addition is nearing completion. The proposed Biology building is under design and construction should commence in early 1991.

Housing Planning: As more attention becomes focused on this issue by all segments of the MIT community, the Planning Office has continued in its efforts to identify the scale and quality of that need and its financial, physical, and social implications for Institute policy and community life. Graduate student housing at the newly renovated 143 Albany Street is open for the 1990-91 academic year; organizational and site studies for new undergraduate housing on Vassar Street will be completed in FY 1991. As a result of a study undertaken by the planning Office on behalf of the Independent Residence Development Fund (IRDF), the Institute has acquired property on Commonwealth Avenue in Boston's Back Bay to be used as MIT's first sorority house. With renovations funded by the sorority (Alpha Phi) and the IRDF, occupancy by some 60 women is scheduled for August 1991.

Handicap Access Planning: As part of its standing commitment to ease and equality of access to MIT facilities, 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.

Academic Planning and Support: A variety of materials were produced by the Office's Institutional Research Group in support of academic planning. These include developing and maintaining an electronic database of statistical information from the Provost's Five Year Plan, an annual report for the Provost's Office on the ROTC programs, the development and distribution of both hardcopy and electronic (Hypercard) formats for the *MIT Factbook*, development of a comprehensive set of academic and administrative department profiles, and staff support for the President's Committee on Family and Work.

O. ROBERT SIMHA

Safety Office

The first full year of self-insurance for Workers' Compensation produced significant short-term savings as expected. However, while it was hoped this program would reduce the costs and improve efficiency, recordable injuries showed a decrease in frequency but an increase in severity, resulting in essentially the same number of workdays lost as last year. Consequently, further analysis of trends is necessary to determine the magnitude of long-term savings.

Education and Training

The Accident Prevention Guide is currently being programmed on to the Technology Information Network. This will allow on-line access to the Guide within the Institute and through computer networking to other universities and interested parties.

As a result of new safety standards set by the Occupational Safety and Health Administration, the Safety Office has initiated a number of training seminars and has distributed informational bulletins concerning the control of potentially hazardous energy sources (lockout/tagout), personal protective equipment, confined space, and the laboratory chemical hygiene standard.

Hazardous Materials

With assistance from the Industrial Hygiene Office and the Chemistry Department, procedures were implemented to enable using the Purchasing Department computer to facilitate the annual Superfund Amendments and Reauthorization Act (SARA) inventory. Procedures were also developed and implemented to review purchases of large quantities of chemicals.

A chemical exchange program has been developed with the Department of Chemistry to redistribute chemicals no longer needed by the department. Currently 10,000 containers of chemicals have been collected and are offered to potential Institute users.

The volume of disposable chemical waste remained similar to last year. Disposal of polychlorinated biphenyls (PCB's) continues to add a large volume to the total disposed waste since PCB transformers and capacitors continue to be disposed of by various departments.

Fire Protection

The High Rise Sprinkler program continues to move ahead slowly. Installation schedules have been developed for the next few years but difficulties with procedural matters have slowed progress, placing more emphasis on planning.

There were no fire losses last year which exceeded the insurance deductible of \$5,000.

Safety Audits

The annual safety audits by Kemper Insurance and the City of Cambridge Inspectional Services went smoothly this year due to the prompt elimination of newly discovered hazardous conditions.

The Biology Department initiated more formal safety inspections this year. Fraternities continued to be inspected on a courtesy basis. The Department of Architecture sponsored art in public spaces and all phases of these projects were reviewed for safety purposes.

JOHN M. FRESINA

VICE PRESIDENT AND TREASURER

INTRODUCTION

The success of the Campaign for the future continued during the year. Early in the academic year, plans began for an increase in the \$550 million Campaign goal as the results continued to exceed earlier projections. The process of increasing the goal involved all of the key constituencies in the Campaign including senior officers, faculty, key volunteers, Corporation and Corporation Development Committee members, and the staff. A new goal of \$700 million was voted by the Corporation at its March 2, 1990 meeting, and news of the increase was quickly communicated both within and outside the MIT community.

Gifts and pledges to the Campaign reached \$517.5 million at yearend, an increase of almost exactly \$100 million from the \$417.4 million total 12 months earlier. During the year, MIT received \$103.1 million of gifts which is an increase of 32 percent above the \$78.1 million received in the prior year. This is a new record and is more than three times the gifts received 10 years ago and five times the gifts received 15 years ago.

Pledges represent an important source of future gifts. Outstanding pledges were about \$15 million four years ago and had increased to \$118 million at June 30, 1990. These pledges declined by nearly \$3 million last year as payments slightly exceeded the amount of new pledges added. The high level of pledges provides optimism for a continued strong gift flow.

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, prospect research (Campaign Systems), and school-based fundraising (Development Services). The Treasurer's Office and the Alumni Association carry on important fundraising activities that are closely linked to Resource Development. During the year, a significant effort was made to increase the number of calls to individual prospects and to engage them in MIT functions and activities. We are indebted to John F. Rockart, Senior Lecturer and Director of the Center for Information Systems Research in the Sloan School of Management, whose writings and advice in defining Critical Success Factors were used to establish goals for individual fundraising.

The Corporate fundraising activities are assigned to Corporate Relations which includes both the Industrial Liaison Program and Corporate Development. These two groups were more closely coupled during the year, and a number of large corporate commitments were obtained because of successful efforts of the ILP staff. The Corporate Development staff have identified the dollar amount of proposals made to corporate prospects as the key measure of future success. Efforts were made throughout the year to work closely with faculty and to develop proposals of high quality with good expectations for funding.

Early in the year it was recognized that the success of Foundation Relations was limited by the number of staff supporting the Director and preparing proposals. Additional staff resources were directed to

foundation fundraising, and the results to date have benefited from this change.

Resource Development staffing for the Campaign remained stable during the year with the addition of five newly hired staff, made up of three women, including one Black American, and two men. There were 23 promotions (61 percent women), including eight from support to staff positions. Since the close of the fiscal year, Development Services has added an Associate Director to support selected academic departments in the School of Science, and a staff member transferred from the Chairman's Office to become Associate Director of Corporate Relations. We continue to seek qualified women and underrepresented minority applicants for open positions.

D. Hugh Darden retired as Director of Capital Gifts and Legal Affairs, but continues part time activities as Associate Treasurer. Frank H. McGrory succeeded Mr. Darden as Director on January 1, 1990, and also became Associate Treasurer.

PRIVATE SUPPORT

Private support for fiscal year 1990 totaled \$111.1 million, including the following: \$103.1 million in gifts, grants, and bequests, and \$8.0 million in support through membership in the Industrial Liaison Program. The total, which is the highest in MIT's history, compares with \$86.9 million in 1989, \$91.9 million in 1988, \$76.4 million in 1987, and \$62.8 million in 1986. Gifts-in-kind for the past year (principally gifts of equipment) were valued at \$13.8 million and are not included in the amounts above.

Sources of gifts for fiscal year 1990 were: alumni, \$34.7 million; non-alumni friends, \$13.3 million; corporations, corporate foundations, and trade associations, \$36.4 million; foundations and charitable trusts, \$18.5 million; and others, \$0.2 million.

Donors designated expendable and endowed funds as follows: unrestricted, \$16.2 million; departments, \$37.7 million; faculty salaries, \$13.5 million; graduate student aid, \$9.3 million; undergraduate student aid, \$7.5 million; building construction funds, \$0.5 million; and other funds \$18.4 million.

Private support in 1990 helped increase the commitments for the Campaign to \$517.5 million, representing 74 percent of the new \$700 million goal set for June 1992. By Campaign priority, commitments raised and percentage of goal achieved were the following: Endowment for Faculty Chairs, \$71.5 million (65%); Academic Programs, \$248.6 million (83%); Student Support, \$72.5 million (60%); New and Renovated Facilities, \$14.4 million (21%); and Unrestricted Gifts, \$86.5 million (86%). In addition, commitments totaling \$24 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.

Research for these activities is headed by Judith Mangan, Assistant Director - Research, who was promoted to this position from support staff in April 1990. The research group prepared more than 100 solicitation and cultivation plans, and produced prospect profiles, managed strategy sessions, and qualified prospects.

Major Gifts strengthened its focus on prospects in the New York Metropolitan area capable of making gifts of \$50,000 or more to MIT. Prospect management is the responsibility of Ronald A. Thomann, Associate Director, who came to the Institute in July of 1989; Branger Miller, Major Gifts Officer, who joined MIT in September 1989; and Laura Quinn, Major Gifts Officer, who was promoted to this position in March 1990 from Assistant Director for Major Gifts Research. She replaced Margaret E. Gutowski, who resigned.

In fiscal year 1990, a high rate of solicitation and cultivation activity continued with prospects considered to have major gift potential, and the staff managed 57 solicitation visits and 54 cultivation visits. Fifteen stewardship events were also held both on and off the campus attended by 123 prospects. The objectives of these events are to honor donors as well as to effectively cultivate the honorees and other invited guests. Highlighting these events, President Gray spoke at gatherings hosted by Thomas Perkins '53 in Belvedere, California; T. Wilson '53 in Seattle, Washington; and John Hennessey '70 in New York at Credit Suisse First Boston headquarters. In addition, Mrs. Eugene McDermott met with some of the recipients of her scholarship funds; and George Macomber '48 and Robert Metcalfe '68 and the respective faculty members whom they support were honored off campus in Boston and Woodside, California, respectively. Finally, cultivation dinners for European corporate and individual prospects were hosted by Chairman David Saxon in London and Paris in May. The growth and importance of stewardship is reflective of the need for high level, ongoing cultivation of major donors.

As a result of more than 110 trips to the New York Metropolitan area in fiscal year 1990, the New York Metro area team actively recruited new volunteers, identified potential donors, and managed a record number of volunteer solicitations. Through cultivation events and personal visits, they personally qualified the philanthropic capacity and inclination of more than 200 alumni prospects and recruited 16 new volunteers for roles on the New York, New Jersey and Westchester/Fairfield Campaign Committees. Volunteers and staff made 102 solicitations. They also managed 10 cultivation events, actively cultivating over 100 Campaign prospects. Particularly significant were a dinner hosted by Elliot Wolk '57 at his home featuring Associate Provost for the Arts Ellen Harris; a planned giving luncheon hosted by Thomas Creamer '40; and a luncheon hosted by Albert Weis '48 at which Professor Robert Solow spoke.

The Major Gifts Office is also responsible for individual donor relations. This involves drafting, processing, and coordinating all presidential appreciation letters for individual donor gifts, and Chairman appreciation letters for donor pledges (generally \$1,000-\$4,999), as well as other letters of appreciation. During the year more than 1400 letters were prepared for the President's and Chairman's approval and signature.

NATIONAL CAMPAIGN

The emphasis this year was in significantly increasing the level of activity in the area of personal cultivation and solicitation. The goal set mid-year for each District Director was to reach an average level of one cultivation or solicitation visit per day to their prospects either by themselves, volunteers, senior administrative staff, faculty, or any combination thereof. For the last half of the fiscal year, the field staff has managed nearly 500 visits. To support the high level of personal visitation, numerous small cultivation events were hosted by many National Campaign Committee volunteers throughout the country. The objective is to continue this vigorous rate of activity for the balance of the Campaign.

Highlights of the many cultivation events produced this year included a dinner with White House Chief of Staff John Sununu '61, five area Campaign dinners, and a reception for alumni founders of companies in Silicon Valley. This event, following the success of Event 128 for Boston founders in April 1989, attracted nearly 200 founders and guests. A local economic impact study sponsored by The Chase Manhattan Corporation entitled, "MIT: Entrepreneurship in Silicon Valley" was distributed to the guests and the press, resulting in favorable publicity.

In cooperation with the Alumni/ae Association, progress was made in developing the Parents Program. The first Family Weekend was held on campus in October, a reception for parents was held in New York City in February, four issues of the new Parents News were published, and several parents were recruited as volunteers for both relational and fundraising purposes. Considerable progress was also made in organizing cultivation activities that would be of interest to the widows of alumni. Much enthusiasm has been shown for this type of program by the volunteers recruited by Betsy Millard, Senior District Director-Special Constituencies.

Henry B. Barg, Director of Campaign Operations, reported the following personnel changes in the National Campaign Office: early in the fiscal year Marilyn K. Kuhar and John W. Larson were promoted to Associate Director; Sarah M. Carothers, Joy J. Carrigan, Dianne M. Goldin and Betsy Millard had a change in their titles to Senior District Director; and V. Meredith Thomas was promoted to District Director from Assistant Manager of Sustaining Fellows and Special Events; in May, John W. Larson resigned his position.

Sustaining Fellows and Special Events

The Sustaining Fellows program continued under the direction of Cassandra N. Page. The high point for many members was the Sustaining Fellows event on October 4, 1989, at the Four Seasons Hotel, Boston, which honored Founding Life members Professor and Mrs. Harold E. Edgerton '27. Among the 300 members and friends of MIT attending were four colleagues and students who gave personal anecdotes about their years with "Doc," who then captivated everyone with his reminiscences about his years as an entrepreneur and educator.

A revised annual membership list with a letter from Dr. Saxon was sent in November to over 1000 Sustaining Fellows. Between September 1989 and June 1990, the Special Events and Sustaining Fellows Office managed or

coordinated 20 events which were held on campus and in other parts of the country. Many of the 1600 people who attended these events were Sustaining Fellows. Throughout the year, stewardship was a major focus for this office. There was also contact with many Sustaining Fellows and MIT alumni who visited or reached the office by phone or letter.

On July 1, 1989, Marsha Edmunds was promoted from support staff to Assistant Manager for Sustaining Fellows and Special Events, filling the position vacated by Meredith Thomas.

Campus Visit Program

During its fourth year of operation the Campus Visit Office managed by Estelle Cashman held six campus visits - three in the fall and three in the spring - with 197 alumni, spouses and friends of MIT attending. While the program for every Campus Visit included a wide variety of Institute activities, each visit had a special focus: The School of Humanities and Social Science; Undergraduate Education (for members of the 40th reunion Class of '51); The MIT Sloan School of Management; The Report of the Commission on Industrial Productivity; Science and Creativity at MIT; and High Technology for Entrepreneurs (repeating a successful program format for the third year in a row). The content of the visits included programs and laboratory tours that allowed for lively interaction between campus visitors, students and faculty members.

The format for each 36-hour visit has been similar: an opening reception and dinner at the MIT Museum Thursday evening; a full day of informational programs on Friday, followed by dinner at the President's House hosted by Dr. and Mrs. Gray, (except the October visit hosted by Honorary Chairman and Mrs. Howard W. Johnson at the Museum of Science), and a wrap-up breakfast Saturday morning at the Cambridge Center Marriott where campus visitors stay as guests of the Institute.

Since the Campus Visit program began in October 1986, 373 MIT alumni and friends (with their spouses or guests) have attended 23 Campus Visits. By the end of fiscal 1990, almost \$30 million in gifts and pledges had been received from these Campus Visitors in response to solicitations made after their Campus Visit attendance. There have been 172 MIT professors and teachers presenting 139 programs during the course of the visits, with 50 participating in two or more presentations. Each of the MIT provosts and deans, as well as two former MIT Presidents (Howard W. Johnson and Jerome B. Wiesner) has participated in Campus Visit programs. An average of 15 students, in addition to undergraduates from the MIT performing ensembles, have also been involved in each Campus Visit, participating in the programs and/or joining the visitors for meals.

The Campus Visit program continues to highlight MIT faculty and students, two of the best reasons to support MIT. However, another very important element in the success of these visits has been the active participation of President and Mrs. Gray, both by sending personal invitations to these visits and by hosting the dinners at the President's House. The effectiveness of their warmth and hospitality in the Campus Visit cultivation and stewardship process has been critical to the success of the program.

OFFICE OF CAMPAIGN SYSTEMS

The Office of Campaign Systems continued to provide research and information management support to the Campaign. The office, directed by

Shelley Brown, consists of a research group, a programming group, a production systems support unit, and an administrative and research support area.

The research operation supported the National Campaign Office and its network of volunteers as well as the New York Metro Team in the Office of Major Gifts. The office also provided research for Campaign events (including Campus Visits) and for the recently established Parents Program. Almost 1,400 requests for information were met.

The programming staff continued their efforts to support the ADDS Efficiency Project, undertaken jointly with other MIT departments to reduce the costs associated with the ADDS database. The Project was brought to successful conclusion in January, with the main files of the database and key programs converted to Natural 2.1. The staff also responded to over 600 adhoc programming requests.

The production and systems support area provided training and software and hardware maintenance to the 60 Macintosh users throughout Resource Development. The staff also handled the production support for Campaign cultivation events, Campus Visits, and Campaign mailings.

Lisa Peterson, Assistant Director, resigned this year. Her responsibilities were distributed between Susan Cronin Ruderman, who was promoted to Assistant Director, and Nancy L. Olt, Assistant Director. Two support staff members were promoted to administrative staff positions: Rita Catalano Jellison to Assistant to the Director; Barbara McDonald to Administrative Assistant.

OFFICE OF DEVELOPMENT SERVICES AND SCHOOL-BASED FUNDRAISING

The Office of Development Services works closely with the school development officers, faculty and the Office of the Provost to coordinate fundraising efforts with the central development staff and to provide a centralized source of fundraising support services: prospect research, proposal preparation, project management and stewardship programs. While remaining largely focused on project-driven fundraising, Development Services has significantly expanded its stewardship roles within the past year as the Campaign has generated many new naming gifts, especially professorships, fellowships and scholarships. It has also taken a much more active role in the coordination of fundraising with respect to student aid and professorships.

In support of other school-based initiatives during fiscal year 1990, the research staff responded to over 140 requests for information on potential donors, and the professional staff prepared over 70 proposals and 60 stewardship reports.

Jack Oldham, the Director, manages the research and professional staff, and works with key faculty on developing larger fundraising strategies and projects, particularly those that involve more than one school. This year, for example, he worked with Professor Daniel Roos and the Center for Technology, Policy, and Industrial Development to raise a \$2.06 million Sloan Foundation research grant on productivity and best practice within the auto industry.

John Jacoby, who was promoted to Associate Director, serves as liaison between the Office of the Provost and the Campaign staff. Fundraising

priorities within the Office of the Provost have included support for underrepresented minority graduate students, fellowships for women in science and engineering, public service fellowships within MIT's new Public Service Center and the undergraduate education component of the Campaign.

In the School of Management, Director Nathaniel Mayes led staff efforts to raise funds for several initiatives including professorships, fellowships, and research programs. Among the highlights are the collaboration funded by the Nanyang Technological Institute with a \$10 million pledge over five years to enhance academic activities relating to the global economy, and the new Research Patron Program.

David Lundberg, Associate Dean for Development in the School of Humanities and Social Science, directed efforts to identify individual, corporate, and foundation funding sources for professorships and particular faculty projects in the school.

In addition to working on these activities, the Assistant Directors supported a wide variety of school-based fundraising initiatives. These included, as examples, raising funds for the renovation and expansion of the library and graduate fellowships in Architecture and Planning; and funding for faculty and school-based projects in Engineering, including the New Products Program, Microsystems Industrial Group, the Program in Polymer Science and Technology, Hazardous Substances Management, and the Nuclear Engineering Department's Computer Imaging Project.

Cordelia Foell joined the staff as Associate Director in July 1990 and will support the fundraising activities of the Dean and certain departments in the School of Science.

Janice Steingesser was promoted to Assistant Director and assumed additional student aid fundraising and stewardship responsibilities. James Paterson was promoted to Senior Research Analyst and supported several school-based activities.

CORPORATE RELATIONS

The major task of the Corporate Relations Group this past year has been to broaden its activities in support of relationships between MIT and industry with the goal of increasing the intellectual and financial support of MIT. This effort has meant even closer collaboration between Corporate Relations staff and the faculty, and the involvement of the staff in a much wider range of endeavors. The group is headed by Eric Johnson, Director of Corporate Relations. Thomas Moebus, Director of the Industrial Liaison Program (ILP), and Frederick Gross, Director of Corporate Development, manage major portions of the activities.

By the end of the year, nearly all of the Industrial Liaison Officers, the largest group within Corporate Relations, had experience with providing stewardship of major corporate gifts or research contracts and with cultivating and developing approaches to firms for major gift support, in addition to serving their ILP memberships. The result is a staff which much better understands the broader spectrum of relationships companies have with MIT and, therefore, which has a stronger ability to serve those relationships.

Corporate gifts for the year totaled \$33.9 million, representing a 30% increase over the previous year. A significant part of the increase in corporate gift support resulted from the efforts of the ILP staff as they became involved in major gift approaches. This contribution will continue to increase in the future, particularly as several major funding initiatives take shape.

To support those developing initiatives, several special staff assignments have been made. For example, Cynthia D. LuBien, Senior Liaison Officer, has been working about half time with the Chemistry Department to support their efforts to develop major gifts. This has resulted in an increase in support for the Department and a significant increase in proposals. Joseph E. Baclawski, Senior Liaison Officer, has been working closely with the Leaders for Manufacturing Program, including keeping effective contact with the industrial sponsors. This involvement will be particularly helpful as the Institute develops additional ties with industry in the manufacturing arena. David Marsh, Manager of Corporate Relations, has, since the middle of the year, devoted his attention to developing closer links with the telecommunications industry.

As the activities of the Corporate Relations Group have broadened to include many new aspects of corporate ties to MIT, it is also important to assure that an effective ILP is maintained. The Liaison Program and its services to members remain at the center of the efforts to maintain effective relationships with companies. Statistically, the results for the ILP this past year were not as good as had been hoped. Membership declined to the level of 255 members, and fee income was down 6% from the previous year. U.S. memberships declined as corporate restructuring and economic conditions caused a number of companies to leave the Program, and new members did not fully replace these losses. Memberships overseas increased slightly.

In February, two appointments were made to strengthen the Liaison Program and to help continue its success. First, Thomas R. Moebus was promoted to Director to assure both the continuation of the best program of its type and a sufficient number of new members to replace those who may leave due to mergers, declining business conditions, or decisions to focus their support elsewhere at MIT. In addition, Cynthia B. Bloomquist, Associate Director of Corporate Relations, will spend full time developing new memberships in the Program.

During the year, personnel changes included several members of the staff who left to pursue other opportunities: Peter N. Cerundolo, Manager of Corporate Relations; Sarah Fisher, Associate Liaison Officer; and Junco Norton, Administrative Officer. Wendy M. Elliott joined the staff as an Industrial Liaison Officer and in July 1990 Paul Murphy was appointed as the new Administrative Officer.

NATIONAL BUSINESS COMMITTEE

Robert Hagopian, Director, utilized his accumulated expertise and alumni contacts to develop new relations with corporations. He also coordinated National Campaign activities in Canada, Pittsburgh and Seattle where Campaign dinners were held, and committees were organized. He continued to assist newer staff members throughout Resource Development in their country-wide efforts, helping identify potential volunteers and arranging cultivation and solicitation visits with alumni. He serves as liaison

for Resource Development relationships with the Alumni/ae Association in the selection of volunteers for offices, committees, and awards.

FOUNDATION RELATIONS

The staff in Foundation Relations, under the direction of Barbara Stowe, expanded MIT's efforts to secure support for research and educational programs in science, engineering and the humanities. Commitments received during the year totaled \$30 million. Significant new foundation grants were received for activities related to science literacy, neurobiology, brain sciences, and for programs to provide expanded opportunities for women and other underrepresented minority students. Susannah Wolfson, Senior Research Analyst, joined the group this past year.

CORPORATION DEVELOPMENT COMMITTEE

The annual meeting attended by 57 members of the Corporation Development Committee (CDC) was held in Cambridge on October 5, 1989, bridging the Sustaining Fellows event honoring Harold "Doc" Edgerton on October 4 and the Corporation Meeting on October 6. In contrast to other years, the meeting lasted throughout the day with the morning devoted to a report of Campaign progress and the mechanisms used for setting a new Campaign goal, later announced in March of 1990. After presentations by Senior Officers and key volunteers, six Institute senior administrators discussed their areas of responsibility and answered questions. The Dalton Bowl was awarded to Raymond S. Stata '57 for his dedicated volunteer leadership on behalf of MIT.

During lunch the CDC members were introduced to Ellen T. Harris, MIT's new Associate Provost for the Arts and Professor of Music, who made a presentation on the role of the arts at MIT. The afternoon session consisted of a panel of students describing their recruitment, involvement, and expectations for the MIT Leaders for Manufacturing program. Frank H. McGrory, Associate Director of Capital Gifts and Legal Affairs, gave a presentation on "Ways of Giving" to heighten CDC members' awareness of the many ways gifts can be made to the Institute. The program was assembled and coordinated by a staff headed by H. E. (George) Ramonat, Executive Director.

COMMUNICATIONS

During this Campaign, the Communications staff has been responsible for a variety of projects from videos to direct mail pamphlets. Some have aimed at conveying impressions and information about MIT's mission and accomplishments; others have presented the case for specific Campaign priorities; still others have tracked progress for different constituencies. Elizabeth Harding, Director, also coordinated the staff that provided support to the setting of priorities and communications for the increase in the Campaign goal.

The most ambitious publication is Spectrum, a 16-page newspaper which puts particular emphasis on profiles of MIT people - students, faculty and alumni. Four issues were produced in 1989-90, including one that provided a retrospective of the Gray presidency. Spectrum is widely distributed within the Institute and mailed elsewhere to over 9,000 alumni and friends.

In the fall, the staff brought out the second issue of Campaign Reports, a six-page newsletter reporting on volunteer activity and progress. A publication, Parents News, is being prepared quarterly in conjunction with the new MIT Parents Program.

This past year a series of "donor profiles," designed to inform alumni about planned giving options, was continued in Technology Review. The office once again produced MIT Facts, a 44-page booklet presenting a brief, general overview of the Institute. New projects included a brochure on classroom renovation, a Campaign priority; a periodic column, Campaign Update, appears in Tech Talk; and public relations support for Special Campaign events.

GLENN P. STREHLE

ALUMNI ASSOCIATION

Since I returned to MIT to assume the position of Executive Vice President and Chief Executive Officer of the Association ten years ago, the Alumni Association has gone through substantial changes. During that ten year period, we have added 22,000 alumni/ae to our 1979 base of 65,000. Of that, almost 5,000 were women, more than doubling the total number of alumnae. Our volunteer leadership continues to take bold new initiative, including the first official visit by an Association President to alumni/ae in Japan. The decade has seen growth in our support for minority alumni/ae. We have also joined three other universities in forming a company called University ProNet to provide computerized referrals about job searches.

Technology Review won many awards, including two Sibleys from CASE (Council for the Advancement and Support of Education), two nominations for the National Magazine Award from the Magazine Publisher's Association, the John Bartlow Martin Award for Public Interest Magazine Journalism from Northwestern University Medill School of Journalism, and numerous design awards. We are now published in Italian through an arrangement with the IRI Group, and in Japanese as a reprint in *B-ing*.

We have more than doubled the Alumni Fund ('79-'80, \$6.32 million; '89-'90, \$16.2 million). We continue into the fourth year of the *Campaign for the Future*, which has reached \$517.45 million toward a revised goal of \$700 million (from \$550 million). Our success in fundraising in this year came in no small measure through the very successful use of a challenge fund provided through the generosity of David Koch '62. This was truly a decade of achievement of which I am quite proud. The real credit is due to over 10,000 volunteers, active for all or part of the decade, and this most able staff. Together they worked hard to achieve an ambitious set of goals.

I owe a deep debt to ten years of Presidents of the Association, ten years of Boards of Directors, and the staff, many of whom still serve in increased roles and responsibilities for the Association. A special vote of thanks goes to Harris Weinstein '56, this year's Association President, whose thoughtful, questioning, and energetic leadership have taken us to new heights of involvement and success.

Mr. Weinstein's classmate, Richard A. Jacobs '56, concluded his second year as Chairman of the Alumni Fund Board with yet another record to his credit. Most able leadership was also provided by R. Gary Schweikhardt GM '73 in taking the work of the MIT Commission on US Productivity, "Made in America," to five US cities with the support of local volunteers and staff.

I must acknowledge the first rate work of two ad hoc committees, one chaired by Wendyl Reis '56 on the Enterprise Forum, and the second on Graduate Program Activities chaired by Karen Mathiasen GM '71.

Finally, the directors, with the able support of the *Technology Review* Advisory Board and its chair, Edward T. Thompson '49, led a restructuring of the oversight of *Technology Review* by dissolving the Advisory Board and empowering a new *Technology Review* Board with an expanded policy role.

It is with continued deep respect and affection for MIT and the alumni/ae that we all, volunteers and staff alike, labor to support the Institute and its precious asset, the larger alumni/ae body.

ALUMNI ACTIVITIES

In a new year marked by the continuing success of the Alumni Fund, the Alumni Activities group underwent further change reducing the number of staff units from five to three. Individual reports are submitted below.

In its 50th anniversary year, the Alumni Fund, led by Mr. Jacobs, and buoyed by the generous Challenge Fund provided by Mr. Koch, set a new record with contributions of \$16.2 million, a 12 percent increase over 1989, and a new million dollar plateau. The impact of the Koch Challenge, which matched increased contributions to the Fund of \$100 or greater to a maximum match of \$1,000 per individual, was substantial. The number of alumni/ae who gave \$100 or greater increased to 13,620, representing 48 percent of the donors. Of the 28,090 alumni/ae contributors, more than 10,000 earned Koch Challenge Funds. Corporate matching gifts grew to nearly \$2 million, a one-year increase of 27 percent. Included in the Alumni Fund for the first time were gifts, totalling \$109,000, from some 300 non-alumni parents.

As the *Campaign for the Future* continues with a new goal of \$700 million, the Alumni Fund has raised its objectives within the overall Campaign goal from \$100 million to \$120 million in gifts and pledges. As of June 30, the Fund has credited \$73.2 million in cash receipts toward its goal, with an additional \$12.2 million received in pledges. Further, with 48 percent of alumni/ae contributing \$100 or greater, the median gift increased to \$75.

As President Gray concludes his service at MIT's president, it is appropriate to note the growth in the Alumni Fund during his tenure. In the past decade, the Fund has increased 157 percent to \$16.2 million from a 1980 base of \$6.3 million, while the total number of contributors reached 29,000, a 23 percent increase. Corporate matching gifts grew from \$650,000 to nearly \$2 million. Additionally, the number of alumni donors at specific targeted levels of \$1,000 or greater, \$250 or greater, and \$100 or greater increased dramatically. Specifically, the number of alumni giving \$100 or more grew to 13,600 from a 1980 base of 5,000, an increase of 170 percent.

ALUMNI FUND VISIT PROGRAM

The Alumni Fund Visit Program was initiated in 1987 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.

During the 1989-90 Fund year, there were 15 programs throughout the country in which 109 volunteer alumni/ae solicitors met with 429 prospects and raised over \$711,000, exclusive of corporate matching gifts. Since inception, the program has raised over \$2.6 million, including many five year pledges from 700 alumni/ae who pledged in response to a visit from a fellow graduate, doubling the average gift of these individuals. In the process, a new cadre of some 300 alumni/ae has been identified and trained in solicitation techniques.

TELETHON PROGRAM

The telethon program successfully completed another year of productive contact with an extensive number of alumni/ae and student volunteers reaching over 13,700 alumni/ae during telethons held on campus and in 15 cities throughout the country. Pledges in excess of \$728,000 were made by 72 percent of the alumni/ae contacted. In addition to these highlights, a paid caller telethon pilot produced pledges totalling over \$5,400, with nine MIT students contacting 1,000 alumni/ae during a five week period.

REGIONAL PROGRAMS

Regional club programs continue to thrive under the capable leadership of local alumni/ae boards and officers who arrange to have faculty speakers, plant tours, and other relevant events to stimulate MIT presence in local communities.

This year was highlighted by a successful Boston speaker series, "Windows on MIT," featuring all nine Nobel laureates. The MIT Commission on Productivity also went "on the road" to Seattle, San Francisco, Los Angeles, Detroit, Chicago, Dallas, and Houston to publicize the recent book *Made In America: Regaining the Productive Edge*, which gave insights into American manufacturing competitiveness. Combined attendance at these events was 1,282, including both alumni/ae and non-alumni/ae.

Each of our 70 world wide clubs remains vital to the MIT fabric and continues to exhibit commitment and support to MIT through their diverse programs.

CLASS PROGRAMS

An overflow crowd attended the Technology Day 1990 program, a debate on the predictability of global warming featuring presentations by MIT's Professor Robert Lindzen of the Department of Earth Atmospheric and Planetary Sciences (EAPS), and Dr. Stephen Schneider, Head of the Interdisciplinary Climate Systems Program at the National Center for Atmospheric Research in Boulder, Colorado. Professor Ronald Prinn CM '71, also of the EAPS department, served as moderator. Commentaries were given by Professor Nazli Choucri, Professor of Political Science and Associate Director of the Technology and Development Program, and by Professor Henry Jacoby, Professor in the Sloan School of Management and Chair of the MIT faculty. The afternoon program began the EAPS centenary celebration with department-sponsored open houses and a series of lectures given by Professors Timothy Grove, Thomas Jordan, Mario Molino, Ronald Prinn CM'71 and Jack Wisdom, all members of the EAPS faculty.

Fifteen reunion classes (1915-1985) were represented among the over 2,400 alumni and guests who participated in Alumni/ae Week activities. Traditional activities included the Thursday evening Tech Night at Pops, the annual alumni memorial service in the MIT Chapel and the presentation of eight reunion class gifts and the senior class gift at the Technology Day luncheon. New this year were the first annual alumni games following a barbecue lunch on Saturday and a young alumni gala event on Saturday evening. Over 130 alumni and their guests celebrated the new Cardinal and Gray Society reunion tradition with President Emeritus Julius A. Stratton '23 and Professor Irwin Sizer HM.

Gifts of the 25th, 40th and 50th reunion classes totalled nearly \$13 million. The 50th reunion class of 1940 broke last year's modern record with a gift of \$5.9 million. This gift included the Barton L. Weller Professorship and the Barton L. Weller Research Fund. Also announced by the Class of 1940 was \$1.3 million in future gifts to MIT. The 40th reunion class of 1950 raised \$4.6 million, including \$1 million new dollars to the Class of 1950 Financial Aid Fund, the largest class-supported scholarship fund. The class of 1965's 25th reunion gift was \$2.2 million including over \$250,000 designated to the Frederick Fassett Fund, an unrestricted endowment fund.

Other reunion gifts announced were as follows: Class of 1985 5th reunion, \$29,950; Class of 1980 10th reunion, \$56,890; Class of 1975 15th reunion, \$87,221; Class of 1930 60th reunion, \$824,800; Class of 1925 65th reunion, \$1,770,000. Two hundred twenty-six seniors participated in a senior gift of \$15,800 which included matching funds from the Koch Challenge and the Class of 1940 Challenge Fund. The Class of 1990 gift is a clock tower to be located at the student center.

The 68 class agents acknowledged many of the 19,000 gifts made to the Alumni Fund by undergraduate alumni and sent their annual letters encouraging class member participation in the Fund. For the second year the class of 1948 gift, \$487,600, was the largest non-reunion class gift; 55 classes achieved or exceeded the Alumni Fund campaign-end median gift goal of \$100; the class of 1928 had the highest participation rate with 66% of its members participating in the 1990 Fund.

ALUMNI/AE LEADERSHIP CONFERENCE

The 1989 Alumni/ae Leadership Conference, held on Saturday, September 23, was attended by more than 400 alumni/ae leaders. During the day-long program, these volunteers were greeted by MIT President Paul E. Gray '54 and, at the annual awards luncheon, Alumni Association President Harris Weinstein '56, who presented awards recognizing 21 alumni for their outstanding service to the Institute and Presidential Citations to alumni/ae organizations.

The morning program included a seminar on admissions policy moderated by Bonny Kellermann '72, Director for the Educational Council and Associate Director of Admissions, with panel members Michael Behnke, Director of Admissions; and Associate Professor Keith Stolzenbach '66, Associate Professor and past chairman of the Committee on Undergraduate Admissions and Financial Aid (CUAFA). During the Alumni Association annual meeting, reports were presented by President Weinstein; Mr. Jacobs, chairman of the Alumni Fund; and Carl Mueller '41, chairman of the Presidential Search Committee. Following the annual meeting, Executive Vice President William J. Hecht '61 moderated a volunteer's briefing session with presentations from Glenn P. Strehle '58, Vice President for Development and Treasurer; John M. Deutch '61, Provost; Shirley M. McBay, Dean of Student Affairs; and Professor Margaret L. A. MacVicar '65, Dean for Undergraduate Education and Professor of Physical Science.

The afternoon program consisted of three concurrent sessions presented by Professors Alex H. Slocum '82, Assistant Professor, Civil Engineering; Harry West ME'86, Assistant Professor, Mechanical Engineering; and Frank Solomon, Professor of Biology.

GRADUATE ALUMNI PROGRAM

Nearly 9,000 graduate alumni/ae contributed \$2.7 million to the Alumni Fund during the past year, representing a 4% increase in dollars and 362 first-time gifts from graduates in the most recent five years. Nineteen department heads sent letters soliciting gifts from their alumni and 16 departments held telethons to encourage support. In addition, the Graduate Student Council and Ashdown House cosponsored a telethon to raise funds for graduate student housing. The graduate alumni telethons involved 271 volunteer callers, nearly twice the number who volunteered in the previous year.

In September over 300 alumni/ae and friends celebrated the 50th anniversary of the Aeronautics and Astronautics Department. In June the 100th Anniversary of Earth Sciences at MIT was recognized by the Earth, Atmospheric and Planetary Sciences Department centenary activities. A successful series of educational, service, and social events was begun this year for Boston area undergraduate and graduate alumni who received degrees in the most recent ten years. The second annual send-off dinner series was attended by 522 graduate degree recipients and their guests. Keynote speakers were Karen Arenson '70, Paul Levy '72, Professor Seymour Papert, and John Reed '61.

STUDENT PROGRAMS

The goals of Student Programs are to bring undergraduate students together with alumni/ae and to acquaint undergraduates with Alumni/ae Association programs. During the past year, approximately 500 students spoke with alumni/ae about their careers by participating in the freshman banquet and career focus receptions. Over 600 seniors enjoyed dinner and conversation with 60 alumni/ae at the home of President and Mrs. Gray during the month of February. Another 1,300 students stopped by the Association's finals week lounge held in the Bush Room. Some 1,000 undergraduate students also participated in such Association programs as the Alumni/ae Leadership Conference, the Student Telethon, a paid caller program and the Senior Gift/Pledge Program.

PARENTS PROGRAM

A 40 member Parents Committee was established in this past year to advise the Parents Program. Parents, students, and faculty joined in planning the first Family Weekend attended by 1,300 parents and students. *Parents News*, a newsletter produced jointly by the Alumni Association, Resource Development, and the Office of the Dean of Student Affairs, was sent quarterly to parents. The program sent two complimentary issues of *Technology Review* to parents. Gifts from MIT parents in this first full year of the program totaled \$235,000.

YOUNG ALUMNI PROGRAM

This year saw the launching of many non-fundraising activities for young alumni. The newly formed eleven member young alumni steering committee, composed of undergraduate and graduate members, planned and implemented several successful young alumni activities in the Boston area including public service, career planning, and social gatherings. With the encouragement of Association staff, young alumni in other regions of the country are planning and organizing, through their clubs, events geared to recent graduates.

As a way of maintaining the link between recent graduates and the Institute, the young alumni newsletter, *The Intelligencer*, was mailed to young alumni volunteers in the fall and spring. In addition, a new publication, *Passport to MIT in the Real World*, was sent to the Class of 1989 resulting in many class members expressing an interest in becoming involved in MIT clubs and as MIT volunteers.

SPECIAL PROGRAMS

Association of MIT Alumnae (AMITA)

This spring, AMITA established the AMITA/UROP Oral History Project, to document the experiences and contributions of MIT alumnae. Some 161 alumnae have contributed \$24,000 in gifts and pledges toward this project. Other AMITA activities for the year included publication of a quarterly newsletter, the annual meeting of AMITA at Endicott House with guest speaker Professor Sheila Widnall '60, and the annual presentation of the AMITA Senior Academic Award to Sima Setayeshgar '90 and Charissa Y. Lin '90.

Black Alumni of MIT (BAMIT)

In 1988, the BAMIT Scholarship Fund was renamed the McNair Scholarship Endowment Fund, to honor Ronald E. McNair G'77 the black astronaut and MIT alumnus who lost his life in the 1986 *Challenger* accident. To date over \$50,000 in gifts and pledges have been raised to benefit minority students. In October 1989, Elizabeth Quinn '90 was named the first McNair Scholar.

Other BAMIT activities included the annual National Meeting, highlighting successful alternative science and engineering programs for minority youth; the annual exit reception for minority graduates; quarterly newsletters; and monthly meetings of local BAMIT chapters and the Executive Committee. In what appears to be an exciting new collaboration, the MIT Club of Washington, DC invited Leslie Spencer '85, Treasurer of the BAMIT Club of Washington, to serve as an advisory member of its Board of Directors.

Latino Association of MIT Alumni/ae (LAMITA)

Organized in the summer of 1989, LAMITA's objectives are to serve as a vehicle for service to the Latino community, particularly in promoting science and math education in local school systems, and to serve as a voice within MIT for Latino concerns.

Boston Seminar Series

Over 170 subscribers attended the 1989-1990 Boston Seminar Series titled *America in Review - Are We Really #1?*, which was chaired for the second year by Arthur Winston PH'54. Guest speakers included Dr. Suzanne Berger, Department Head, Political Science, MIT, Ford International Professor of Political Science; Dr. George Hatsopoulos '49, Chairman and President, Thermo Electron Corporation; Joshua Rubenstein, Northeast Regional Director, Amnesty International; Dr. Gray, President, MIT; Ira C. Magaziner, President, Telesis, Inc.; Dr. Hou Zi Qiang, Secretary General, Chinese Academy of Sciences, Deputy Director and Professor, Institute of Acoustics.

ALUMNI ACTIVITIES STAFF

As noted earlier, the Activities Group underwent further change this year. Following the resignation of Associate Director Mary K. Norman, the Alumni Fund Visit Program was placed under the aegis of Janet L. Serman, who is responsible now for all regional programs. Further, the departure of Associate Director Jeffrey R. Solof '81, who left the Association to join MIT's Information Systems Group, caused a merger of the programs reporting to him with the Classes and Events Group. This new staff group, titled Classes and Special Programs, reports to Diana Strange, who was promoted to the position of Senior Associate Director. Responsibility for Telethon Programs was assumed by Assistant Director Joseph P. Recchio. Other staff changes included the promotions of Elizabeth A. Garvin and Gloria Hodgens to Program Directors, and Laura M. Scarlett to a new position as Assistant to the Managing Director. David M. Libby '85 was appointed Coordinator within the Major Reunion Gift Group, and Sylvia Crone was appointed Administrator of the MIT Alumni Center of New York. Jennifer Archibald resigned as Program Director for Graduate Alumni Programs. It is with sadness that we report the sudden death of B. Frank Smith AR '68, Senior Regional Director at the MIT Alumni Center in New York since 1981.

Finally, it is noteworthy that the continuing reorganization of the Activities staff proceeded smoothly with marked improvements in the ability of the staff to support alumni and stimulate new program initiatives. In the end, however, the success of the Fund and other alumni programs stems from the leadership, time, and energy provided by countless numbers of alumni/ae volunteers.

ALUMNI ASSOCIATION AWARDS

Bronze Beaver Awards

S. Martin Billett '48; Robert L. Mitchell CH '47; William Rousseau '36; Raymond S. Stata '57.

Harold E. Lobdell '17 Distinguished Service Awards

David Adams '50; Denis A. Bovin '69; George F. Clifford '48; Ernest Kaswell '39; James Phinney HM; Russell Robinson '32; Steven Swibel; Gregory R. Turner '74.

George B. Morgan '20 Award

Burton Agnell '43; William A. Avent '42; Michael Biancardi '40; Norman A. Chrisman, Jr. '49; Robert Gooch '51.

Henry B. Kane '24 Award

Edgar P. Eaton, Jr. '44; Lewis H. Roosa '49; Chenery Salmon '26; Bennett M. Zarren '61.

President Citation Award

MIT Class of 1939; Cleveland Alumni Fund Visit Program; MIT Club of Dallas/Fort Worth; MIT Club of Southwest Florida.

Honorary Membership

Norma Mele.

TECHNOLOGY REVIEW

The governing structure of *Technology Review* was modified in the past year to allow the Alumni/ae Association's Board of Directors to do a better job exercising its responsibility as the magazine's owner. The review's former advisory board was disbanded, and a new *Technology Review* Board was established. It is appointed by the Board of Directors, generally from names suggested by the *Technology Review* Board chair, the president and the executive vice president of the Association, and the editor of the review. The *Technology Review* Board, which includes a number of members with expertise in magazine publishing, supervises the review's business affairs and advises on editorial matters.

A redesign of *Technology Review's* national pages appeared in the January 1990 issue. We are now redesigning the inside section that goes to the MIT community. We sought to make the magazine more visually consistent and easier to read. We gave greater prominence to the *MIT Reporter* section (on developments at the Institute), moving it from the back to the front of the magazine and giving it more pages. We included an explicit statement in the contents page that *Technology Review* does not represent Institute policy for anyone who might imagine that it did.

PWe have done very well on circulation, again making a small profit on first-year subscribers; promotional costs were slightly lower than the resulting subscription income, an unusual success for any magazine. Advertising revenue was lower than expected -- as has been the case for the entire magazine business -- but our overall income was about \$100,000 more than budgeted, while we stayed essentially on budget for our expenses.

Internal Revenue Service regulations required the Association to establish a value for an alumni subscription to *Technology Review*. The Board of Directors chose the figure of \$25; the average subscriber pays about \$20 but does not receive the MIT section. The Board of Directors also raised the minimum donation alumni/ae must make to receive the review to \$35 for anyone more than five years out of school. In the past, increasing the minimum donation for the review has raised overall minimum levels of alumni donations; we hope that this will occur in Fiscal Year 1992.

ALUMNI INFORMATION MANAGEMENT

With the help of two outside consultants from Logic Unlimited, Inc., Information Management was able to develop and implement an interactive Parents Program subsystem and to rewrite over 300 ADABAS Natural programs into a more effective, less expensive form of program.

We have improved our programming staff by hiring an experienced ADABAS Natural programmer. Our programming group is processing 60 weekly ad hoc requests, having reduced the turn-around time from 3-5 days to 1-3 days.

For Reunions, our on-line Events system was significantly improved with the creation of tickets for each activity. The alumnus' name and the date and location of the activity are printed on the tickets, so we can now direct lost alumni/ae to their destination merely by looking at their tickets.

Our office continues to find "lost" alumni/ae using the latest means available to us. A recent purchase of a Nynex CD-ROM reader has enabled us to find over 500 missing telephone numbers.

Our mailing addresses were analyzed by the United States Post Office to determine whether our addresses were valid according to postal regulations. "Operation Mail" determined that 85% of our mailings were delivered.

ADMINISTRATIVE SERVICES

Two long-time MIT staff members retired from the Association this year. Alice Moriarty had a long career at MIT, including time with both Doc Draper '26 and Dean William Pound, former Dean of the Sloan School of Management. She retired from supporting Joseph S. Collins H, Managing Director, Alumni Activities and Director of the Alumni Fund. Marion Redonnet, my energetic administrative assistant, retired after 11 years at the Association following several earlier years in the Department of Urban Studies and Planning. Both represent the committed, caring staff who contribute so much to this collaboration of able volunteers and staff.

The majority of Administrative Services' time was devoted to upgrading and maintenance of the personnel database, which will allow us to provide managers with in-depth profiles of their areas, and to further refining the Alumni/ae Association accounting and financial control systems. Through successful collaboration with a hard-working audit and budget committee chaired by Peter M. Saint Germain '48, Katherine Cochrane and Patricia Kane and their staff provided a much improved planning and budget process and package. Genevieve Hammond, Administrative Assistant, was named co-convenor of the MIT Working Group on Support Staff Issues; Ms. Hammond will serve a two-year term. Linda Manion of the *Technology Review* staff has been named a member of this group.

WILLIAM J. HECHT '61